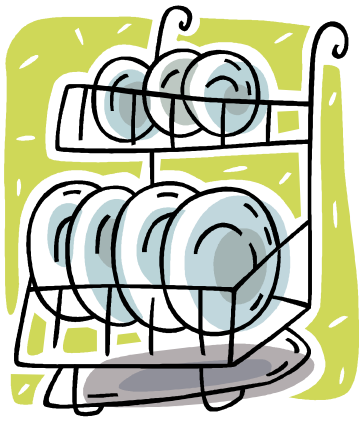

Michigan Department of Agriculture

Training Program for the Professional Food Service Sanitarian

Module 4: Facility Operations

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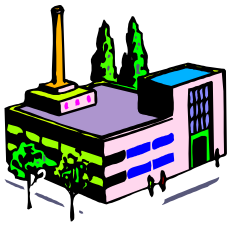
Good Manufacturing Practices



Objective

At the completion of this module, participants will be able to apply knowledge of sanitation and Good Manufacturing Practices to evaluate controls for in-plant environmental conditions.

Introduction

Food safety can be controlled through *process controls*, or those controls that affect the way food moves through the equipment and process to ensure a safe product.

But for those controls to work, they must be accompanied by *prerequisite programs - those steps or procedures that control the in-plant environmental conditions that provide the foundation for safe food production*. Examples of prerequisite programs are: sanitation, good manufacturing practices (GMPs), training, recall programs and preventive maintenance programs. This section covers sanitation and GMPs.

Areas of Sanitation

There are eight broad areas of sanitation that are the most important in ensuring that food products are processed under sanitary conditions. These areas of sanitation apply to food retailers, wholesalers, warehouses, and manufacturing operations of all types.

(1) Safety of water

This area relates to water quality and treatment of water that comes into direct contact with food or food contact surfaces, or that is used in the manufacturing of ice. It also relates to cross connections between potable and non-potable water systems.

Food processors must have adequate supply of potable water at a suitable temperature. In the case of water from wells, state and local officials usually approve well construction and perform periodic, generally annual analysis for total coliform and other water quality properties. Well heads must be sloped away from the well to encourage proper drainage. They should also be sealed to prevent entry of runoff water.

There must be properly designed plumbing for water, wastewater, and sewage, with no cross connections which would allow back siphonage. During inspections, water and sewage lines should be traced to find cross connections and dead areas.

Some of the key areas where cross connections occur in processing operations include:

Hose bibs: Typically a vacuum breaker or other type of back flow prevention device is needed to avoid a negative pressure situation. Negative pressure occurs when suction is exerted on the water line, changing the normal positive pressure to negative pressure. So, if a hose is submerged in water, on the floor or in a tank, the dirty water can be sucked up into the potable water supply unless the line is protected with a back flow prevention device.

Wash/thaw/rinse tanks: Water should not enter the tank below the flood rim. Again, if there was a negative pressure situation, the wash water would be sucked up into the potable water supply. In these situations, an air gap of two (2) times the diameter of the water entry pipe (and in no case less than 1") must be provided between the water entry pipe and the rim of the tank to prevent back siphonage.

When ice comes in contact with food or food contact surfaces it must be manufactured and stored in a sanitary manner. For this reason, ice bins must be properly constructed using food grade surfaces. Food and insanitary objects must not be stored in the ice. And the ice must be protected from contamination by employees walking on the ice. The interior of ice machines should be examined to insure that it is clean and no cross connections exist.

(2) The condition and cleanliness of food contact surfaces

This area relates to the design, workmanship, materials, maintenance, cleaning and sanitizing of food contact surfaces, including gloves and outer garments.

Food contact surfaces need to be cleaned and, when necessary for safety, sanitized before use and after interruptions in food preparation or processing. The key point here is that they must be cleaned first, and then sanitized.

Inspectors need to judge the adequacy of cleaning. To do that, they need to look in areas that are difficult to clean, and where product residues may be present. Places such as under the surface of a processing table or below holes that have been drilled in the surface of a table for drainage, where product residues have accumulated, are ideal places for microorganisms to flourish.

Design and installation of equipment so that it can easily be cleaned, plays a big roll in sanitation. Equipment needs to be designed so that there are no rough welds, cracks, or depression that protect bacteria from cleaning and sanitizing compounds. There should be a smooth transition between surfaces, where the different surfaces are bonded. Equipment also needs to be designed so that all of the parts, from the surface to the interior to the framework, can be easily cleaned.

Another concern is equipment that was well designed, but which has outlived its usefulness and has become so scratched and pitted that it can no longer be adequately cleaned. This equipment should be repaired or replaced.

Equipment must be made from materials that can be used for food contact surfaces. Materials such as wood, which is porous and difficult if not impossible to clean, are not an acceptable food contact surface. Food contact surfaces are any surfaces that product comes in contact with. If product comes in contact with a wall, then the wall is a product contact surface and is subject to the same design, maintenance and washing requirements.

Other product contact surfaces are those that employees contact, and then contact the food product, without washing and sanitizing their hands in between. Some examples of these are cooler or rest room door handles, trash containers and raw material packages which cannot be washed or sanitized adequately.

Gloves are also food contact surfaces and need to be made from a suitable material and maintained in a satisfactory condition. Gloves do not solve the sanitation issues associated with product handling. They can transmit bacteria - as well as hands do - but can be cleaned a little easier than hands because they are not as porous. Washing and sanitizing of gloves is equally as important as bare hand sanitation. If gloves are not properly maintained, and develop holes, they can become a source of product contamination.

Storage of gloves while not in use can also be a problem. They must be stored in a location where they will not become contaminated. Cloth gloves should be discouraged, as they are porous and not easily cleaned. Cloth gloves should never be used to handle cooked ready-to-eat product, because they may contribute to re-contamination of the product.

Every food processing facility should have procedures that provide for the adequate cleaning and sanitation of gloves if they are used. The firm's procedures should also provide for clean outer garments for use by processing employees. Street cloths should never come into contact with food products.

(3) Prevention of cross contamination

This area of sanitation relates to employee practices that are designed to prevent contamination; physical separation of raw and cooked product; and plant design to prevent contamination.

Employee practices:

Proper hand washing and sanitizing can prevent contamination. The purpose of hand washing is to remove organic matter and transient bacteria, so that sanitizing can effectively reduce and eliminate bacteria. But hand washing and sanitizing may not be effective if employees wear jewelry or covering over their fingers, like duct tape or adhesive bandages. Organic matter can lodge between the skin and the jewelry or the tape - where ideal conditions result in subsequent rapid microbial growth, which of course serves as a source of contamination.

Personal items can also contribute to contamination and need to be stored away from production areas. They can harbor filth and bacteria from outside the plant. Storage facilities do not have to be elaborate locker rooms and can even be small closets, as long as it is away from the production area.

Practices such as eating, drinking or smoking in production areas should not happen. That is basic food sanitation. In almost all of these situations, the hands come in close proximity with the nose, and the nose harbors *Staphylococcus* organisms in about 50% of the healthy population.

Skin contaminants are also a concern. Elbows, arms and other uncovered skin surfaces should not come into contact with food or food preparation surfaces.

Physical separation:

One way to prevent cross contamination is to provide adequate space for processing operations. State and local officials generally review processing plant blueprints before construction with a goal of minimizing spacial problems. Space problems generally occur with the addition of product lines, increased production, and the installation of new equipment.

Raw food materials and finished products must be separated during production and storage to prevent cross contamination. Examples of where cross contamination may occur are contact between live and cooked crabs or an institutional refrigerator used to store raw meat and poultry products as well as finished ready to eat food products. Separation of the raw and finished products must be carefully controlled to prevent contamination of the ready to eat foods. Separate refrigerators for raw materials and finished products is the best solution to this cross contamination concern.

Employee procedures:

Employee handling procedures can also contribute to product contamination. This happens when employees handle non-contact food surfaces and then handle food products without washing and sanitizing their hands.

Food preparation surfaces must be maintained in a clean and sanitary condition. This includes insuring that the food contact surface is not contaminated by actions such as setting containers or raw material packages which have contacted floors onto clean table tops, or contaminating food preparation surfaces with water splash off from floors or other areas of processing equipment.

(4) Maintenance of hand-washing, hand-sanitizing and toilet facilities

This area also includes proper sewage disposal. State and local officials generally approve individual septic systems. Inspections should reveal problems that sewage handling systems might present.

Unapproved sewage disposal systems pose a public health hazard, as they are a direct fecal source. When septic systems are used the system must be closed and drainage fields cannot be open to the environment, including ponds, lakes and estuaries. Well-maintained privies may be an acceptable means of sewage disposal

depending upon local regulations. But if they are used, they must be constructed to provide for adequate ventilation, screened to prevent insect entry, and located away from food production areas. Oxidation ponds can be an effective means of treating sewage, but its proximity to the plant may cause it to serve as a fecal source.

Toilets need to be accessible, sanitary and in good repair, with self closing doors that do not open to the processing area. The concern is for air-borne pathogens as well as access of vermin to both areas. Inspections should include flushing each toilet in every plant. Many do not function properly and can allow fecal material to contaminate the floor. If the seal around the toilet does leak, it is easy for an employee to pick up the fecal material on their shoes and transport it into the processing area.

Hand washing and hand sanitizing stations need to be conveniently located. If they are not convenient, they won't be used. But they should not be so close as to present a risk of contamination of the product. There needs to be hot and cold mixed water, soap, and disposable towels or other suitable methods of hand drying such as hot air. The hand washing stations need to be constructed to prevent recontamination. A knee activated valve, automatic electronic valve, or foot activated valve is ideal. Inspections should include testing a number of hand washing stations to insure that they are working properly.

A common practice is the use of sanitizer dips on worktables. The idea here is for the employee to dip their hands or utensils as they become soiled to keep the microbial load down. But under the best conditions, those that assure the proper sanitizer strength, this is not effective because hands and utensils become covered with organic matter that will shield the bacteria from the action of the sanitizer. Under typical conditions, the sanitizer will be used up while oxidizing the organic matter with no remaining sanitizer to inhibit growth. So, these dip stations can actually serve as a source of contamination and should be discouraged.

(5) Protection from adulterants and (6) labeling storage and use of toxic compounds

These two areas relate to protecting food from various microbiological, chemical and physical contaminants such as lubricants, fuel, pesticides, cleaning compounds, sanitizing agents, condensate and others. A few examples are:

Drip and condensate: Drip and condensate can contaminate product and need to be prevented. Steam environments are especially hard to control, and condensate that forms on evaporator pans in coolers can also be a problem where the product is being stored below and is subject to the condensate drip. *Listeria* has often been associated with the cooler environment.

Ventilation: Ventilation is often used to reduce condensate formation and noxious odors. However, make sure it does not create other problems such as blowing the condensate into the product or blowing dust and other contaminates into the product.

Lighting: With lighting comes the risk of glass breakage and possible contamination of the food product. Light bulbs must be covered with shields or be coated in plastic. Light shields must be intact with end caps in place.

Storage of toxic materials: Certain toxic materials are needed in a plant where food is being processed, for example, cleaning compounds; laboratory chemicals; those used for equipment maintenance; and those necessary in the plants operation, such as food additives. But, any items that are necessary need to be properly labeled and stored away from the processing area in their own designated area. If possible cleaning compounds and other toxic and corrosive compounds should be stored in a locked storage area, which is accessible only to those individuals, trained in their use.

(7) Employee health conditions

This area relates to the exclusion of persons who appear to have an illness, wound, or other affliction that could be a source of microbial contamination. Processors should have a program to exclude these affected employees from working with and around food products.

(8) Exclusion of pests

Excluding pests such as rodents, birds, and insects which carry a variety of human disease agents is essential to maintaining sanitation of food and food preparation areas.

Primary to pest control is to minimizing the factors that attract the pests, such as debris, unused equipment, product waste and uncut vegetation. Windows, doors and other openings, such as open eves, drainage holes and cracks around plumbing pipes, which lead into the processing facility should be closed, screened or protected (e.g. through the use of air curtains), to prevent the entry of insects, birds, rodents and other pest into the firm. Safe and effective pest control must start outside the plant, with the removal of harborage areas and any food sources such as food waste.

Domestic animals, such as cats used for pest control, and dogs that may be used as guard or companion animals should not be allowed in food production and storage areas. Contamination of food by these animals poses the same risk as contamination by animal pest.

For the most part, compliance with good manufacturing practices and sanitation requirements are the foundation for safe food production. The table that follows takes each of the eight sanitation areas and relates them to specific citations in FDA's 21 CFR Part 110, Good Manufacturing Practice regulations.

Additional guidance on GMPs and requirements for the sanitary production and storage of food products can be found in FDA's "CURRENT GOOD MANUFACTURING PRACTICE IN MANUFACTURING, PACKING, OR HOLDING

HUMAN FOODS" 21 CFR Part 110, and in the U.S. Public Health Service, FDA "1999 Food Code".

EIGHT AREAS OF SANITATION AND THEIR RELATIONSHIP TO THE REQUIREMENTS OF THE FOOD GMPS

Eight Areas of Sanitation	Corresponding Part 110 Requirements
(1) Safety of process water	.37(a); .80(a)(1)&(b)(16): Process water safe and of adequate sanitary quality; water used for washing; rinsing; or conveying of safe and adequate sanitary quality; water used for ice manufacture of safe and adequate sanitary quality .37(b)(5): No cross connections between sewer or wastewater and process water
(2) Condition and cleanliness of food contact surfaces	.40(a)&(b): Food contact surfaces designed, fabricated, maintained, and installed to be adequately cleaned and to withstand the environment of use and cleaning compounds; smoothly bonded seams .35(d)(2); .80(b)(1)&(b)(10)&(b)13(ii): When cleaning is necessary to protect against introduction of microorganisms, clean and sanitize before use, after interruptions, and as necessary .10(b)(1)&(5): Gloves should be impermeable, clean, and sanitary; outer garments suitable
(3) Prevention of cross contamination	.10(b)&(b)(2)&(b)(3)&(b)(4)&(b)(7)&(b)(8)&(b)(9); .80(b)(6)& (b)(13)(v): Food handlers conform to hygienic practices to the extent necessary to prevent contamination; maintain adequate personal cleanliness; wash, and sanitize if necessary, hands before start work, after absence from work station, and

Eight Areas of Sanitation	Corresponding Part 110 Requirements
	when become contaminated; taking precautions as necessary to protect against contamination with microorganisms; effective measures to prevent finished product contamination by raw materials, other ingredients, refuse; remove jewelry that cannot be sanitized; abstaining from eating, chewing gum, drinking, or using tobacco near exposed food or equipment; storing clothing or personal items away from exposed food and equipment .20(b)(1)&(2)&(4): Plant design must reduce potential for contamination of food, food contact surfaces, and packaging material and must permit employees to protect against contamination of food from clothing or personal contact; separation of operations
(4) Maintenance of hand washing, hand sanitizing, and toilet facilities	.37(e)&(e)(1)-(4): Hand washing and, where appropriate, hand sanitizing facilities should be at each location where good sanitary practice dictates their use; effective hand-cleaning and sanitizing preparations; water at suitable temperature; sanitary towel service or suitable drying devices; designed to prevent recontamination .37(c)&(d): Adequate sewage disposal system; adequate, readily accessible toilet facilities; maintained in sanitary condition; self-closing doors; protect food from airborne contamination

Eight Areas of Sanitation	Corresponding Part 110 Requirements
(5) Protection from adulteration	.40(a);.80&(a)(5)&(a)(7)&(b)(5)&(b)(7)&(b)(10)&(b)(12)&(b) (13); .93: Design, construction, and use of equipment precludes adulteration of food with lubricants, fuel, metal fragments, contaminated water, or other contaminants; all reasonable measures to ensure that production methods do not contribute contamination; raw materials held to protect against contamination; work-in-progress handled to protect against contamination; equipment protects food from contamination; mechanical steps protect food from contamination; batters, breadings, sauces, dressing, etc. protected from contamination; filling, assembly, packaging, and other operations protect food from contamination; storage and transportation protect the food from contamination .20(b)(4);.80(b)(10)&(b)(12) (iv): Drip or condensate from fixtures, ducts and pipes does not contaminate food, food contact surfaces, or packaging material; Adequate physical protection of food from contaminants that may drip, drain, or be drawn into the food should be provided .40(g): Compressed air or other gases mechanically introduced treated to prevent contamination of food
(6) Proper labeling, storage, and use of toxic compounds	.35(b)(2)&(c): Toxic cleaning compounds, sanitizing agents, and pesticides identified, held, and stored in a manner that protects food, food contact surfaces, and packaging

Eight Areas of Sanitation	Corresponding Part 110 Requirements
	material from contamination; all relevant regulations for their use followed; pesticides used only when food, food contact surfaces, and packaging material protected from contamination
(7) Control of employee health conditions	.10(a): Food handler who has illness or open lesion, or other source of microbiological contamination that presents reasonable possibility of contamination of food, food contact surface, or packaging material excluded from such operations
(8) Exclusion of pests	.35(c): No pests shall be allowed in any area of a food plant

Cleaning and Sanitizing

Definitions

Chelation - The action of an organic compound attaching itself to the water hardness particles and inactivates them so they will not combine with other material in the water and precipitate out.

Cleaning - A process which will remove soil and prevent accumulation of food residues which may decompose or support the growth of disease causing organisms or the production of toxins.

Deflocculation or Dispersion - The action which groups or clumps of particles are broken up into individual particles and spread out suspended in the solution.

Detergents - Cleaning agents or compounds that modify the nature of water so that it may efficiently penetrate, dislodge and carry away surface contamination.

Disinfectant - usually a chemical agent which destroys germs or other harmful organisms or which inactivates viruses. Most commonly used to designate chemicals that kill growing forms but not necessarily resistant spore forms of bacteria, except where the intended use is specifically against an organism forming spore or a virus, in which instance, the spores too may be killed or the virus inactivated.

Dissolving - The reaction which produces water soluble materials from water insoluble soil.

Emulsification - is a physical action in which fats are mechanically broken up into very small particles which are uniformly suspended in a solution.

Penetration - The action of liquids entering porous materials through cracks, pin holes, or small channels.

Peptization - Physical formation of colloidal solutions from partially soluble materials.

Precipitation - Soften water by precipitating out the hardness.

Rinsability - The action which will break the surface tension of the water in the solution and permit the utensil to drain dry.

Sanitizing - a process which destroys a disease causing organisms which may be present on equipment and utensils after cleaning.

Sanitizing Agent - is an agent that reduces the number of bacterial contaminants to safe levels, as may be judged by public health requirements. Chemical sanitizer used shall meet the requirements of 21 CFR 178.1 01 0.

Saponification - the chemical reaction between an alkali and a fat in which soap is produced.

Sequestering Agents - compounds which will react with certain ions to form relatively stable, water soluble complexes. Polyphosphates are often used in detergent formulations to prevent precipitation.

Sequestration - The action of an inorganic compound attaching itself to the water hardness particles and inactivates them so they will not combine with other material in the water and precipitate out.

Soap - is a sodium or potassium salt with a long chain organic acid.

Soil - matter out of place.

Sterilization - implies the complete destruction of all microorganisms.

Suspension - The action in which insoluble particles are held in solution and not allowed to settle out onto the utensils.

Synergism - A chemical used as a builder with a soap or detergent, which results in a detergency which is greater than the total detergency of the chemical and the soap if they were used independently.

Wetting - Action of water in contacting all soil, helps to reduce surface tension, (wetting agents usually do a good job of emulsification).

Cleaning

Cleaning is a process which will remove soil and prevent accumulation of food residues which may decompose or support the growth of disease causing organisms or the production of toxins.

Listed below are the five basic types of cleaning compounds and their major functions:

1 Basic- Alkalis - Soften the water (by precipitation of the hardness ions), and saponify fats (the chemical reaction between an alkali and a fat in which soap is produced). .

2. Complex Phosphates - Emulsify fats and oils, disperse and suspend oils, peptize proteins, soften water by sequestering, and provide rinsability characteristics without being corrosive.

3 Surfactant - (Wetting Agents) Emulsify fats, disperse fats, provide wetting properties, form suds, and provide rinsability characteristics without being corrosive.

4. Chelating - (Organic compounds) Soften the water by sequestering, prevent mineral deposits, and peptize proteins without being corrosive.

5. Acids - Good at mineral deposit control; and soften the water.

When considering a good cleaner the following properties should be considered:

1. Quick and complete solubility.
2. Good wetting or penetrating action.
3. Dissolving action of food solids.
4. Emulsifying action on fat.
5. Deflocculating, dispersing, or suspending action.
6. Good rinsing properties.
7. Complete water softening power.
8. Noncorrosive on metal surfaces.
9. Germicidal action.
10. Economical to use.

The factors that affect cleaning efficiency are:

1. Selecting the right cleaner for the job.
2. Increasing the temperature of the cleaning solution so that the strength of the bond between the soil and surface is decreased, the viscosity is decreased, and the solubility of the soluble materials and the chemical reaction rate is increased.
3. Increasing the turbulence "elbow grease".
4. Increasing the time the cleaner has contact with the surface needing to be cleaned.
5. Increasing the concentration. Concentration is the least effective variable to change in cleaning.

The cleaning operation:

1 . Prewash - the removal of gross food particles before applying the cleaning solution. This may be accomplished by flushing the equipment surface with cold or warm water under moderate pressure. Very hot water or steam should not be used because it may make cleaning more difficult.

2. Washing - the application of the cleaning compound. There are many methods of subjecting the surface of equipment to cleaning compounds and solutions. Effectiveness and the economy of the method generally dictates its use.

   A. Soaking - immersion in a cleaning solution - The cleaning solution should be hot (125 degrees Fahrenheit) and the equipment permitted to soak for 15 - 30 minutes before manually or mechanically scrubbed.

   B. Spray method - spraying cleaning solution on the surface. This method uses a fixed or portable spraying unit with either hot water or steam.

   C. Clean-in-Place systems (C.I.P.) - is an automated cleaning system generally used in conjunction with permanent-welded pipeline systems. Fluid turbulence in the pipeline is considered to be the major source of energy required for soil removal.

   D. Foaming - utilizes a concentrated blend of surfactant developed to be added to highly concentrated solution of either alkaline or acid cleaners. It produces a stable, copious foam when applied with a foam generator. The foam clings to the surface to be cleaned, which increases contact time of the liquid with the soil, and prevents rapid drying and runoff of the liquid cleaner, thereby improving cleaning.

   E. Jelling - utilizes a concentrated powdered-jelling agent which is dissolved in hot water to form a viscous gel. The desired cleaning product is dissolved in the hot gel and the resulting jelled acid or

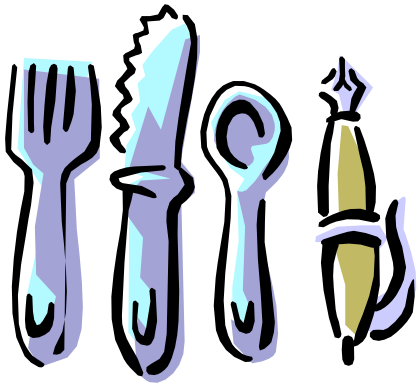
alkaline detergent is sprayed on the surface to be cleaned. The jelled cleaner will hold a thin film on the surface for 10 minutes or longer to attack the soil. Soil and gel are removed with a pressure warm water rinse.

F. Abrasive type powders and pastes - are used for removing difficult soil. Complete rinsing is necessary and care should be taken to avoid scratching stainless steel surfaces. Scouring pads should not be used on food-contact surfaces because small metal pieces from the pads may serve as focal points for corrosion or may be picked up in the food.

3. Rinsing - the removal of all traces of the cleaning solution with clean potable water.

4. Sanitization - a process either by using heat or a chemical concentration that will reduce the bacterial count, including pathogens, to a safe level on utensils and equipment after cleaning.

Sanitizing



The primary reason for the application of effective sanitizing procedures is to destroy those disease organisms which may be present on equipment or utensils after cleaning, and thus prevent the transfer of such organisms to the ultimate consumer. In addition, sanitizing procedures may prevent spoilage of foods or prevent the interference of microorganisms in various industrial processes which depend on pure cultures.

There are two generally accepted methods of providing for the final sanitization of a utensil after effective removal of soil, heat and chemical.

1. Heat

    A. Hot water - an effective, non-selective sanitization method for food-contact surfaces; however, spores may remain alive even after an hour of boiling temperatures. The microbicidal action is thought to be the coagulation of some protein molecules in the cell. The use of hot water has several advantages in that it is readily available, inexpensive and nontoxic. Sanitizing can be accomplished by either pumping the water through assembled equipment or immersing equipment into the water. When pumping it through equipment, the temperature should be maintained to at least 171 F (77 C) for at least 5 minutes as checked at the outlet end of the equipment. When immersing equipment, the water should be maintained at a temperature of a least 171 F (77C) or above for 30 seconds. The water temperature at the manifold for mechanical warewashing equipment must be: single temperature stationary rack = 165 F (74 C), all others = 180 F (82 C).

B. Steam is an excellent agent for treating food equipment. Treatment on heavily contaminated surfaces may cake on the organic residues and prevent lethal heat to penetrate to the microorganism. Steam flow in cabinets should be maintained long enough to keep the thermometer reading above 171 F (77 C) for at least 15 minutes or above 200 F for at least 5 minutes. When steam is used on assembled equipment, the temperature should be maintained at 200 F for at least 5 minutes as checked at the outlet end of the assembled equipment.

2. Chemical

There are a wide variety of known chemicals whose properties destroy or inhibit the growth of microorganisms. Many of these chemicals, however, are not suitable for use on food-contact surfaces because they may corrode, stain or leave a film on the surface. Others may be highly toxic or too expensive for practical use. When looking for an approved sanitizer the label must include:

1. EPA registration number.
2. States that the product may be used on food contact surfaces.
3. Does not require a potable water rinse.
4. States that the product will sanitize. If a product is a detergent/sanitizer, it must also make the claim to clean.

The most commonly used chemical sanitizers for food contact are:

1 . Chlorine and its compounds combine indiscriminately with any and all protein and protoplasm. The mode of bactericidal action is thought to be the reaction of chlorine with certain oxidizable groups in vital enzyme systems.

Advantages	**Disadvantages**
Effective against a wide variety of microorganisms.	Organic matter causes a quick reduction in bactericidal effectiveness.
Not affected by water hardness Non-staining.	Effectiveness decreases as pH increases. Dissipates in hot water.
Concentration easily measured by field tests.	Corrosive.
Generally inexpensive	Irritating to skin.
Non-film forming.	Short shelf life.
	Some odor.

2. Iodophors are soluble complexes of iodine combined usually with non-ionic surface-active agents, loosely bound.

Advantages	Disadvantages
Rapid bacterial action in acid pH range in cold or hard water.	Slow acting at pH 7.0 above, vaporizes at 120'F.
Less affected by organic matter than chlorine.	Less effective against bacterial spores than hypochlorites.
Non-corrosive and non-irritation to skin. Generally spot free drying.	May stain some plastics and porous surfaces.
Stable -- long shelf life.	Relatively expensive.
Visual control (color)	

3. Quaternary Ammonium Compounds are compounds that are synthetic surface-action agents. The most common ones are the cationic detergents which are poor detergents but excellent germicides. In these compounds, the organic radical is the cation and the anion is usually chlorine. The mechanisms of germicidal action is not completely understood, but is associated with enzyme inhibition and leakage of cell constituents.

Advantages	Disadvantages
Non-corrosive.	Not compatible with hard water and most detergents.
Non-irritating to skin.	Forms film.
Stable to heat.	Produces foam in mechanical operations.
Forms bacteriostatic film on surface after treatment.	Selective in destruction or inhibition of various types of organisms.
Relatively stable in presence of organic matter.	Requires higher concentration for action than chlorine or iodine.
Active over a wide pH range.	Relatively expensive.
No taste or odor in use dilutions.	
Broad spectrum of activity.	
Long shelf life.	

Factors affecting the action of chemical sanitizers:

1. Contact of the sanitizer - in order for a chemical to react with microorganisms, it must achieve intimate contact.

2. Selectivity of the sanitized - certain sanitizers are non-selective in their ability to destroy a wide variety of microorganisms while others demonstrate a degree of selectivity. Chlorine is relatively non-selective; however both iodophors and quaternary compounds have a selectivity which may limit their application.

3. Concentration of the sanitizer - in general, the more concentrated a sanitizer, the more rapid and certain its actions. Increases in concentration are usually related to exponential increases in effectiveness until a certain point when it accomplishes less noticeable effectiveness.

   A. A chlorine solution shall have a minimum temperature based- on the concentration and pH of the solution as listed in the following chart;

Minimum Concentration	**Minimum Temperature**	
mg/L	**pH 1 0 or less °C (°F)**	**pH 8 or less °C (°F)**
25	49 (120)	49 (120)
50	38 (100)	24 (75)
100	13 (55)	13 (55)

   B. Iodine solution shall have a:

      1. Minimum temperature of 24°C (75°F),

      2. pH of 5.0 or less or a pH no higher than the level for which the manufacturer specifies the solution is effective, and

      3. Concentration between 12.5 mg/L and 25 mg/L.

C. Quaternary ammonium compound solution shall;

1. Have a minimum temperature of 24°C (75°F),
2. Have a concentration as specified under the requirements specified in 21 CFR 178.1010 and as indicated by the manufacturer's use directions included in the labeling, and
3. Be used only in water with 500 mg/L hardness or less or in water having a hardness no greater than specified by the manufacturer's label.

4. Temperature of solution - all of the common sanitizers increase in activity as the solution temperature increases. This is partly based on the principle that chemical reaction in general are speeded up by raising the temperature. However, a higher temperature also generally lowers surface tension, increases pH, decreases viscosity and effects other changes which may enhance its germicidal action. it should be noted that chlorine compounds are more corrosive at high temperatures, and iodine tends to sublime at temperatures above 120 degrees Fahrenheit.

5. pH of solution - the pH of the solution exerts a very pronounced influence on most sanitizers. Quaternary compounds present a varied reaction to pH depending on the type of organisms being destroyed. Chlorine and iodophor generally decrease in effectiveness with an increase in pH.

6. Time of exposure - sufficient time must be allowed for whatever chemical reactions that occur to destroy the microorganism. The required time will not only depend on the preceding factors, but on microorganism. populations and the populations of cells having varied susceptibility to the sanitizer due to cell age, spore formation, and other physiological factors of the microorganisms.

Dishwashing Machines

Dishwashing machines belong to one of two categories: the hot water or chemical sanitizing type. Standards for manufactures's of these dishwashing machines are provided by NSF International as Standard Number 3. Part of the standard requires:

1 . Hot water sanitizing machines shall specify the following on a permanently attached data plate:

   A. The minimum temperature of the wash water in the tank (unless numerically indicated at the location of temperature indicating device);

   B. The minimum temperature of pumped rinse in the tank, if applicable (unless numerically indicated at the location of temperature indicated device);

   C. The minimum temperature of the final sanitizing rinse at the spray arm manifold (unless numerically indicated at the location of temperature indicting device);

   D. The minimum and maximum pressure in the final sanitizing rinse line with the rinse in operation (not required for machines with a pumped final sanitizing rinse);

   E. The minimum wash and final sanitizing rinse cycle times (stationary rack machines only);

   F. The maximum conveyor speed (conveyor machines only).

Specifications for Hot Water Sanitizing

Type of Dishwashing Machine	Minimum wash temp.	Minimum sanitizing rinse temperature	Maximum sanitizing rinse temperature	Sanitizing rinse pressure
Stationary rack, single temp.	165°F (74°C)	165°F (74°C)	190°F (90°C)	20 psi ± 5 psi (138 kPa ± 34kPa)
Stationary rack/dual temperature	150°F (66°C)	180° F (82°C)	195°F (90°C)	20 psi ± 5 psi (138 kPa ± 34kPa)
Single tank conveyor	160°F (71°C)	180°F (82°C)	195°F (90°C)	20 psi ± 5 psi (138 kPa ± 34kPa)
Multiple tank conveyor	150°F (66°C)	180°F (82°C)	195°F (90°C)	20 psi ± 5 psi (138 kPa ± 34kPa)

2. Chemical sanitizing machines shall specify the following on a permanently attached data plate:

   A. The minimum temperature of wash water in the tank (unless numerically indicated at the location of temperature indicating device);

   B. The minimum temperature of pumped rinse in the tank, if applicable (unless numerically indicated at the location of temperature indicating device);

   C. The minimum temperature of the chemical sanitizing rinse (unless numerically indicated at the location of temperature indicating device);

   D. Type of chemical sanitizer and minimum concentration in the chemical sanitizing rinse;

   E. The maximum and minimum pressure in the chemical sanitizing . rinse line with the rinse in operation (not required for machines with a pumped final sanitizing rinse);

   F. The minimum wash and chemical sanitizing rinse cycle times (stationary rack machines only);

   G. The maximum conveyor speed (conveyor machines only).

Data Plate Specification for the Chemical Sanitizing Rinse

Sanitizing solution type	Final rinse temperature	Concentration
Chlorine	min: 120°F (49°C) *	min: 50 ppm (as NaOCI)
Iodine	min: 75°F (24°C)	min: 12.5 ppm - max: 25 ppm
Quaternary Ammonium	min: 75°F (24°C)	min: 150 ppm - max: 400 ppm

- For glasswashing machines using chlorine sanitizing solution, the minimum final rinse temperature specified by the manufacturer shall be at least 75°F (24°C).

The following are general requirements for a successful dishwashing operation

1. Selection of the proper dishwashing machine, correctly sized to suit the needs of the particular operation.
2. Properly sized and installed water heating equipment to supply the dishwashing operation.
3. Effective layout of the equipment and utilization of labor.
4. Training of the operator in the use and the maintenance of the equipment and the correct use of detergents and/or other chemicals used in the dishwashing process.
5. Managerial surveillance of the operation to determine that the dishwashing procedure is carried out properly by the trained personnel.
6. A protected dish handling and storage system to assure clean dishes when required for use.

The majority of commercial spray-type dishwashing machines on the market today will do the job required of them. The major problems with this type of equipment are operational and require periodical surveillance. Selection of a particular machine for a given operation requires knowledge of the demands to be placed on the machine, type of utensils to be washed, quantity of utensils at peak periods, etc. A properly sized dishwashing machine engineered to conform to the requirements of NSF International standard 3, properly installed and maintained will do a satisfactory job.

When preparing to check a dishmachine begin by reviewing the operational requirements listed on the data plate of the machine. Then check the following:

- Scrape trays clear.
- Conveyor-type machines-curtains intact, clean and in proper position.
- Conveyor speed according to manufacturer's specifications.
- Overflow standpipe in place and not blocked or leaking.
- Wash and rinse pump inlet unobstructed.
- Tank interior clear of buildup of lime, food soils, etc.
- Wash and rinse nozzles clear of obstructions and lime deposits.
- End caps in place on wash and rinse arms.
- Rinse line strainer clear.
- Wash and rinse thermometers accurate or properly calibrated.
- Pressure regulator functioning properly.
- Flow pressure 15 to 25 pounds per square inch (psi) (where required).
- Building water pressure adequate.
- Rinse arm nozzle alignment correct.
- Dishes properly racked.

Proper sanitization in a dishmachine depends on heat accumulation from washing, power rinsing (on some types of machines), and final rinsing. Therefore, each of these cycles must be operating at the proper temperature. To insure this, the following should be determined:

- No lime deposits in heating elements.
- Machine tank gas heater jets not obstructed.
- No excessive ventilation draft in the removal of steam and condensation.
- Maximum-registering, mercury-filled thermometers and thermo-labels (paper thermometers that change color from silver to black when reaching specified temperatures) may be used to confirm the effectiveness of heat sanitization.
- The maximum-registering, mercury-filled thermometer, to give accurate readings, should be attached (rubber bands or clips may be used) in a vertical position. It should also be taken out of any case or guard when used. Thermo-labels are attached by pressure-sensitive adhesive tape preferably on a clean dry china plate. A thermometer can be attached at the gage cock to check the calibration of the final rinse thermometer without removing the final rinse thermometer sensing bulb. However, the thermometer to be attached should have an immersion mark on it and must have a special connection that will allow movement of the stem

through the opening presented when the valve is turned on. The sensor must be inserted into the flowing stream of water or serious errors in readings can occur since cooling will take place between the rinse flow line and the thermometer location. Check the thermorneter that is being used as the calibrating thermometer. Immerse it in the hot water to the immersion mark on the thermometer and take a comparison reading. There will be a difference in reading if the bulb is not immersed to this depth each time. Temperatures must be checked with the rinse activated and water flowing in the line.

- As water falls through space after leaving the rinse spray arms, the drop in temperature is rapid. The temperature developed at the dish surface can be 10° F. to 20° F. lower than the temperature in the manifold. Therefore, a reading on the maximum-registering thermometer of at least 160° F. or a color change in thermopaper at 160° F. should be acceptable.
- Unless the machine is used just prior to testing, run the machine through at least two complete wash and final rinse cycles before taking readings.
- Close adherence to manufacturer's specifications as listed on the machine data plate is very important.

The following is a list of common problems experienced in dishwashers together with suggested remedial action

Symptom	Possible Cause	Suggested Cure
Soiled Dishes	Insufficient detergents	Use enough detergent in wash water to insure complete soil suspension
Soiled Dishes	Wash water temperature too low	Keep water temperature within recommended ranges to dissolve food residues and to further facilitate heat accumulation (for sanitation).
Soiled Dishes	Inadequate wash and rinse times	Allow sufficient time for wash and rinse operations to be effective. (Time should be automatically controlled by timer or by conveyorspeed).
Soiled Dishes	Improperly racking or placing	Rack according to size and type
Film	Water hardness	Use an external softening process. Use more detergent to provide internal conditioning. Use a chlorinated cleaner. Check temperature of wash and rinse water. Water maintained above recommended ranges may precipitate film.
Film	Detergent carryover	Maintain adequate pressure and volume of rinse water.
Film	Improperly cleaned or rinsed equipment	Prevent scale buildup in equipment by adopting frequent and adequate cleaning practices. Maintain adequate pressure and volume of water.
Greasy films	Low pH, insufficient detergent, low water temperature	Maintain adequate alkalinity to saponify greases, check detergent, and water temperature.
Greasy films	Improperly cleaned equipment	Unclog all wash and rinse nozzles to provide proper spray action. Clogged rinse nozzles may also interfere with wash tank overflow.
Streaking	Alkalinity in the water	Use and external treatment method to reduce alkalinity

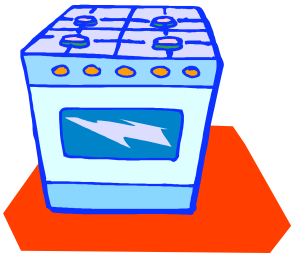
Spotting	Rinse water hardness	Provide external or internal softening
Spotting	Rinse Water temperature too high or too low	Check rinse water temperature. Dishes may be flash drying, or water may be drying on dishes rather than draining off.
Spotting	Inadequate time between rinsing and storage	Allow sufficient time for air drying.
Foaming	Detergent	Change to a low sudsing product.
Foaming	Dissolved or suspended solids in water	Use an appropriate treatment method to reduce the solid content of the water.
Foaming	Food soil	Adequately remove gross soil before washing. The decomposition of carbohydrates, proteins, or fats may cause foaming during the wash cycle.

Cooking At the Retail Level

Objectives

Upon completion of this module, the participants will:

- Have an understanding of the use of cooking to achieve the death of microbes.
- Have an understanding of the factors involved in the destruction of microbes by cooking.
- Recognize various cooking methods and the controls necessary to assure proper reduction of hazards through the cooking process.



1. PURPOSE OF COOKING

Cooking of meat and poultry products changes the foods' color and texture, halts enzymatic action and generally makes food more palatable; however, from a safety standpoint, the most important purpose of heating is to kill or inactivate spoilage and pathogenic organisms.

2. TYPES OF HEATING

This module will discuss the various types of cooking methods and the control procedures to assure the elimination of pathogens; however first let's discuss the way heat is transferred in the cooking processes.

2.1 CONDUCTION

The first method of heat transfer we will discuss is conduction. Heating by conduction is a slow process in which heat is applied to the food container, and the heat is passed on to the food. In conduction heating, heat is transferred through the food being cooked one particle at a time (from one molecule to the next). This type of heating is typical for solid foods such as a turkey or a roast being cooked in an oven. To evaluate the adequacy of cooking, we must know where the coldest point is in the food. The coldest point in conduction heating is usually either the geometric center, or farthest point from the heat source.

2.2 CONVECTION

A faster method of heating is convection heating in which heat penetration is augmented by movement in the food. Convection heating can only occur in foods that can move within the cooking vessel. This movement is referred to as convection currents, an uneven heating within the food, brings them about. For example, in a pot of stew heat moves through the food container walls and heats the material nearest to the wall of the pot. As this part of the food becomes warmer it tends to rise, and the cooler material at the center of the container sinks. We usually observe this type of heating in the form of boiling liquids. These convection currents speed the heating process, and make it more uniform. The coldest spot in convection heating is no longer the geometric center but is nearer the bottom center of the container where the currents diverge.

2.3 FORCED CONVECTION

For even faster heating and more uniformity, forced convection is used. This is convection heating that is facilitated by stirring or agitation. Stirring moves the food around in the heating container and by doing so speeds the heating process. There are a variety of methods for stirring foods at the food processor level, but at the retail level the cook simply stirring the pot usually accomplishes it. The location of the cold spot in forced convection heating depends on the type of stirring involved, however if very active stirring is involved, cold spots are virtually eliminated. Forced convection can also be observed in forced air ovens where forced air circulation facilitates faster heat transfer on the surface of the product.

3. WHAT AFFECTS HEAT RESISTANCE IN BACTERIA

Understanding the penetration of heat into a cooked food is the easy part. Somewhat more difficult to understand is how this heat affects microbes in the food. Not all species of microbes die at the same rate as the result of heat application. In addition, the same species of microbes contained in different types of foods may have very different resistance to heat due to the nature of the food product in which they are contained or their previous growing conditions. There are a number of factors that influence the resistance of bacteria to heat applied during the cooking process and we will discuss some of them.

3.1 NATURE OF BACTERIA (psychrophiles/mesophiles/thermophiles)

Before we discuss the effect of heat on microbes, you should understand that different microorganisms have significantly different tolerance to heat. Because of their very nature, microbes can grow over a wide range of temperatures from about 14°F to 194°F. Microbes are grouped into three categories based on their temperature growth ranges as shown in the table below.

TEMPERATURE GROWTH RANGES

Category	Temperature Optimum Growth	Temperature Growth Range
Psychrophiles	>68° F	32° - 86°F
Mesophiles	98° F	50° - 110° F
Thermophiles	131°F	110° - 194° F

Psychrophiles, which includes such organisms as Listeria monocytogenes can live and grow at refrigerated temperatures. Mesophiles grow at temperatures between 50°F and 110°F; while thermophiles grow at elevated temperatures of 110°F to 194°F. The following table shows the temperature growth ranges of specific pathogens.

GROWTH RANGE TABLE

ORGANISM	GROWTH RANGE (F)
Bacillus cereus	39.2 to 131.0
Clostridium perfringens	50.0 to 125.6
Clostridium botulinum	
Types A&B	50.0 to 118.4
Others	37.9 to 113.0
Escherichia coli	44.6 to 120.9
Listeria monocytogenes	31.3 to 113.0
Salmonella	41.4 to 115.2
Shigella, spp	43.0 to 116.8
Staphylococcus aureus	44.6 to 122.0
Vibrio cholerae	50.0 to 109.4
Vibrio parahaemolyticus	41.0 to 111.0
Yersinia enterocolitica	29.7 to 107.6

Source: Second Edition of the FDA Fish and Fisheries Products Hazards and Control Guide, 1998.

Most, but not all, of the microorganisms of public health concern in foods are

mesophiles and their optimum growth temperature corresponds to the human body temperature. Typically, the higher the temperature (within the growth range), the more rapid the growth of the organism. This can be explained by the fact that growth is catalyzed by enzymatic reactions. The rule of thumb is that for every 18 degrees of F increase in temperature the catalytic rate of an enzyme doubles.

It is not only temperature that affects the rate of growth or destruction of organisms, but also the time of exposure to a set temperature. The goal is to reduce the amount of time that a food is exposed to optimum growth temperatures. Therefore, it is recommended that food products be maintained either above 140°F or below 41°F. Later we will discuss minimizing the time in the 'Danger Zone' by rapid cooling procedures, but for now we will concentrate on the reduction of microbes by cooking. Cooking easily destroys the vegetative cells of psychrophiles and mesophiles, however thermophiies are much more heat resistant.

3.2 SPORES VS. VEGETATIVE CELLS

Since we have mentioned vegetative cells, lets discuss another inherent characteristic of some bacteria. The active growing stage of microbes is known as the vegetative stage of the organism. Vegetative bacterial cells are much more sensitive to heat than are spores. However, many vegetative cells are resistant to cold temperatures, and may survive freezing.

Spores are a dormant stage of the bacteria, and are much more resistant to heat than the vegetative stage. Some spores can survive boiling water for more than an hour, they also hold up well under freezing, and may resist some sanitizing compound. A spore usually develops from a vegetative cell during unfavorable environmental conditions. This is the cell's way of surviving such adverse conditions. Spores, themselves, do not reproduce and grow and would be of little concern if they could never grow again. However, like plant seeds, spores can germinate and grow. Ironically, it takes adverse conditions, such as the thermal shock that occurs during the cooking process, to cause these cells to germinate and once again grow into vegetative cells. These cells possess all of the pathogenic characteristics of the originating cells.

SPORE FORMING AND NONSPORE FORMING PATHOGENS

Spore Forming Pathogens	Non-Spore Forming Pathogens
B. cereus	Campylobacter jejuni
C. botulinum	E. coli
C. perfringens	L. monocytogenes
	S. aureus
	Salmonella spp
	Shigella spp
	Yersinia spp

3.3 TYPE OF FOOD

Characteristics of some foods influence how heat affects the pathogens that may be contained in them. For example, pathogens are more easily destroyed in foods having a low pH (acidic). Also, moisture in a food product improves heat penetration and aids in the destruction of pathogens. On the other hand, sugars or oils in a food can surround bacteria and can insulate and protect them from heat.

3.4 GROWING CONDITIONS

A pathogen that is already under stress is easier to destroy by the heating process. For example, microbes that have grown under unfavorable water activity conditions are easier to destroy by heat. However, sometimes changes in the environmental conditions can favor the survival of microbes. For example, in a 1978 experiment, beef rounds dry roasted to an internal temperature of 145°F were found to have Salmonella on their dry surface that survived the cooking process. (S.J. Goodfellow and W.L. Brown "Fate of Salmonella Inoculated into Beef for Cooking.") It was postulated that this resistance was due to rapid dehydration, which in turn resulted in the Salmonella having a higher resistance to heat.

3.5 HUMIDITY OF THE COOKING VESSEL

Moisture is an excellent conductor of heat, and therefore its presence in a high humidity oven or steamer can greatly increase heat penetration and cooking. To demonstrate, you can place your hand in a dry oven at 350°F, and although you will feel the heat, you would not be burned. However, if you placed your hand in steam from boiling water (212°F), you would immediately receive a severe burn. Moisture or humidity in an oven or other type of cooker has a significant impact on heat transfer. Many cooking processes require either the introduction of moisture into the cooker, or sealing of the container in which the food is cooked to prevent the escape of moisture which is already present. For example, a browning bag which seals moisture in significantly reduces the cooking time for oven roasted turkey. If these required steps are not adhered to, then the cooking process may not achieve the kill step indicated for the recipe.

3.6 WATER ACTIVITY

Bacteria need water as well as food for growth and development. Water in a food product may be freely available, or it may be bound by sugar, salt or other ingredients in the food, and not be available to microbes. The availability of water is described as water activity. Water- activity is measured on a scale of 0 to 1.0 with 1.0 being equal to distilled water. The lowest water activity value at which pathogens will grow is 0.91; however, toxin production can occur at a water activity as low as 0.86.

Although foods with a high water activity level allow for optimal bacterial growth, heat penetration in these foods can be faster because of their moisture content, allowing for faster killing of pathogens contained in them.

APPROXIMATE WATER ACTIVITY LEVELS

Food	Water Activity
Fresh meats (beef and chicken)	0.98 and above
Fermented and cooked sausage Lightly salted pork and beef	0.946 to 0.98
Dried sausage Dried beef	0.85 to 0.93

3.7 EFFECT OF pH

Most bacteria grow best in a medium that is neutral or slightly acidic, and the growth of most bacteria are significantly inhibited in very acidic foods. pH is measured on a scale of from 0 to 14.0 with 7.0 being exactly neutral. pH levels from 7.0 to 14.0 are basic while those below 7.0 are said to be acid. Foods having a pH above 4.6 are considered to be low acid foods, and their pH will not inhibit pathogen growth. Meats and poultry are low acid foods. Foods that have a pH range of 4.6 or below are considered high acid foods. Tomatoes and citrus fruits and a variety of prepared foods such as mayonnaise fall into this category.

High acid foods are seldom the vehicles for pathogens; in fact many foods are acidified to prevent the growth of undesirable microbes. However, it should be pointed out that the pH or 4.6 is not an absolute barrier to pathogen growth. Some pathogens are more resistant to low pH than others. For example E. coli has a pH tolerance range of from 4.0 to 9.0, and E. coli 01 57:H7 in apple juice with a pH below 4.6 has resulted in foodborne illness outbreaks. pH is especially useful in preventing the germination of spores that are not destroyed by most retail cooking process.

APPROXIMATE pH OF MEAT AND POULTRY PRODUCTS

Food	pH Range
Fresh beef	5.6 to 6.4
Ground beef	5.1 to 6.2
Bacon	5.6 to 6.6
Ham	5.9 to 6.1
Veal	6.0
Chicken	6.2 to 6.4

3.8 CUMULATIVE EFFECTS OF GROWTH LIMITING FACTORS ON LETHALITY

There are many factors which affect the growth or destruction of microorganisms in food products. When several of these factors exist at the same time in a food product, they can have a synergistic effect on limiting the growth of microorganisms. For example, the combination of a low pH as well as a low water activity can have a cumulative effect on destruction of microbes during cooking. These same factors (barriers) can also prevent pathogen growth in a cooked food. By applying multiple barriers to a single food product, a higher degree of food safety is assured.

4. THERMAL DEATH CURVES

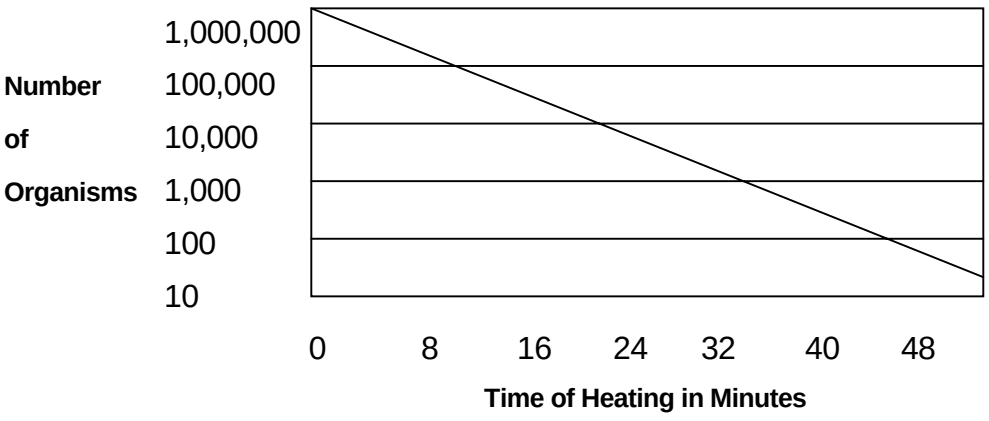
To understand some of the requirements for cooking of meat and poultry, it is important to know some of the concepts of how microorganisms are destroyed by heat. The destruction of microorganisms by heat is a factor of both time and temperature. Microbes in a food subjected to heat do not die all at the same time. As with any living organism, the weaker cells and those subjected to greater stress die first. Generally, the longer organisms are subjected to heat, and the higher the temperature to which they are subjected, the more of them will die. A typical graph showing the death of microorganisms from cooking is a straight-line graph.

4.1 D VALUE = (TIME)

The first concept we will discuss is referred to as the "D Value." This term is used to describe the time at a set temperature needed to kill 90% of the population of a specific microorganism in a specific food at a specified temperature. The table below, shows the effect on an organism held at 180°F for a period of time, and time is the only variable. We start with 1,000,000 organisms, and after 8 minutes, 90% of them have been destroyed, leaving 100,000 organisms. This is referred to as a one decimal log reduction. In this instance D Value = 8 minutes. For every additional 8 minutes at 180°F this process kills an additional 90% of the organisms present.

You may have observed that at this rate, we never reach absolute zero. However, if we apply a sufficient number of D Values, we can reduce the number of pathogens to an acceptable public health level. In the Food Code, a 3, 5, or 7 D Value is applied to meat and poultry cooking processes depending upon the specific food product.

SURVIVORS LOG SCHEDULE



It is important to remember that the D Value for an organism is significantly different at different temperatures. The following graph demonstrates the D Value for the same organism at three different temperatures. As you can see, the D Value changes dramatically when the temperature is varied. It is easy to understand that, as the temperature increases, it takes less time to destroy a population of organisms. Therefore, the D Value (the time needed to kill 90% of the population) becomes smaller as the temperature rises.

4.2 Z VALUE=(TEMPERATURE)

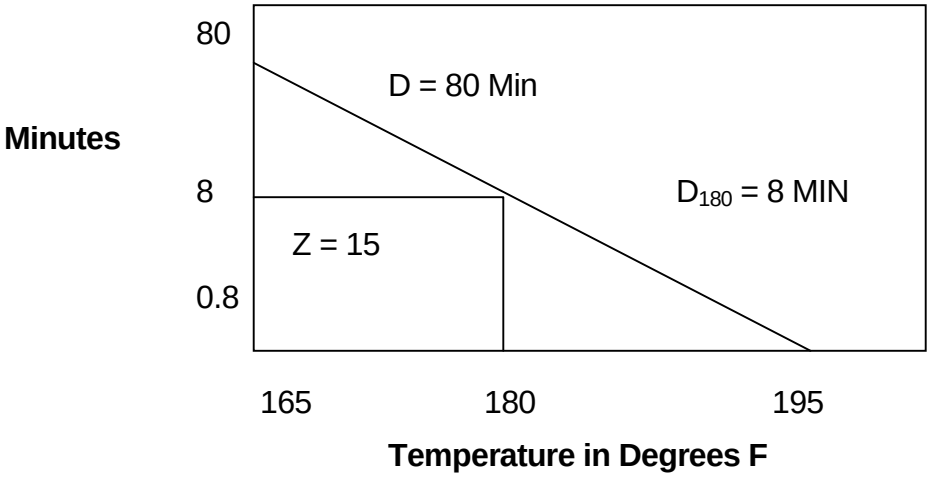
Remember we said that the destruction of microorganisms by heat is a factor of time and temperature. We have already discussed the Factor of time, which is the D Value. The next concept we will address is known as the Z Value, and the Z Value is the number of degrees of temperature necessary to reduce the D Value one log cycle, that is, to kill 90% of the population of a microorganism.

For Z Values, temperature is the variable, with time being constant. If we limit cooking time to a certain number of minutes, then we will have to increase the temperature of the cook in order to reduce the numbers of the target microorganism to a safe level.

In the table below, the D Values from the previous graph are plotted, and you can see the log of the D Value falls in a straight line. In this example an increase of 15°F is needed to achieve each additional D Value. In other words, for each 15° F the temperature is increased, we need only one tenth of the time to kill 90% of the microbes as follows:

a. D Value at 165°F = 80 minutes.

b. D Value at 180°F = 8 minutes.



The D Value describes how sensitive a certain organism is to time at a set temperature. The Z Value describes the organism's sensitivity to temperature for a specified time. Therefore, if we know the D and Z Values for a pathogen we are able to predict how much time is required to destroy the desired numbers of the pathogen at any temperature or any combination of temperatures.

In the real world, however, we do not instantaneously heat to 180F. Also it is improbable in the processing of meat and poultry that a constant temperature will be established and maintained. Because of these variations in the cooking process, the concept of Z Value was established.

If an expert knows the D and Z Values for a food, they are able to calculate lethality tables such as the one in the following table. From these tables, they are able to add up the lethal rate for each minute that the food was held at a certain temperature.

LETHAL RATE AT 180° F = 1

TEMPERATURE (F°)	LETHAL RATE
150	0.010
155	0.021
160	0.046
165	0.100
170	0.215
175	0.464
180	1.000
185	1.154
190	4.642
195	10.000
200	21.544

You can see from the table that for this food, 1 minute at 170°F is equivalent to slightly less than half of the lethality rate at 180°F. By adding the lethality rates for each minute that the food is held at a certain temperature, you end up with an equivalent number of minutes at the reference temperature (in this case-180°F). For example:

One minute	at 160°F =	0.046 plus
One minute	at 170°F =	0.215
Total		0.261

This means that a cook held one minute at 160°F and another minute at 170°F is equivalent to 0.261 minutes at 180'F. This is a simplification of the math process actually used by experts to determine the adequacy of a thermal process. In real world situations, many more factors are considered, and the mathematical formulas are much more complex.

5. IDENTIFYING THE PATHOGENS OF CONCERN

Foodborne Illnesses fall into two categories, the first being an infection and the second being an intoxication. The microorganisms that cause infection and intoxication are all pathogens, but differ in how they affect the body.

Foodborne infections result when-viable pathogens are ingested and attack the host cells. As with any infection, the organism requires time to multiply, therefore the onset of symptoms is rather slow. A common symptom of this type of foodborne illness is fever. Salmonellosis is an example of a foodbome infection. In addition, the illness caused by C. perfringens falls under the foodbome infection classification.

Foodborne intoxication is caused when a specific pathogen grows and produces either an enterotoxin, a toxin contained within the bacterial cell or an exotoxin, which is a waste product of the cell, that is released into the food or the gut of the host. When foods containing either type of toxin are consumed, it is not the organism that causes the illness, but instead, the illness is the result of the toxin. The onset of this type of food illness is much more rapid than a foodbome infection, and a fever does not normally occur in the host. An example is the foodbome intoxication caused by S. aureus toxin.

6. PRESCRIPTIVE REGULATORY LIMITS

The critical limits for cooking meat and poultry are the minimum temperatures that are found in the FDA Food Code, 3401.11 (A) (2) or 3-401.12, and USDA Title 9 Code of Federal Regulations part 318.17 or 318.23. The regulatory limits set by USDA allows for altemative.cooking procedures if they are validated to meet the Food Safety and Inspection Service (FSIS) lethality performance criteria of a 5-decimal log reduction of Salmonella within the product. Production requirements for roast beef were established in 1977 and 1978 following several outbreaks of Salmonella foodborne illness. The requirements covered time, temperature, and in some cases, relative humidity.

The FDA Food Code places emphasis on time and temperature as a unit. Previous model codes placed very little significance on this relationship, however, with the new science of today, and our knowledge of emerging pathogens as well as factors contributing to foodborne illness, it is imperative that time and temperature be considered together. The FDA Food Code incorporates the practical application of this principle by integrating it into the model for states to adopt as state laws and regulations.

Most of the regulatory requirements used by USDA and FDA for time and temperatures are designed to destroy Salmonella, and are based on a 1978 Goodfellow and Brown study "Fate of Salmonella inoculated into beef for cooking." Based on that study, the parameter of 165°F or above for 15 seconds for cooking poultry provides a 7D reduction. Cooking at 155°F for 15 seconds provides a 5D reduction, while cooking at 145°F cook for 15 seconds provides a 3D cook.

Some cooking processes are based on the destruction of pathogens other than Salmonella. For example, the process for cooking ground beef, in addition to providing a 5D reduction in Salmonella, also provides an 8D reduction in the number of E. coli. The cooking process for pork is based on the destruction of trichina.

7. IMPORTANT FACTORS IN THE COOKING PROCESS

The following are some of the important factors in the cooking process.

7.1 HEAT STABLE TOXINS

Although cooking destroys most vegetative cells of pathogens as well as their toxins, not all toxins are easily destroyed by heat. Staphylococcus aureus produces a toxin that results in one of the more economically important dis-eases in the US. S. aureus is very salt tolerant while other foodborne pathogens are not. Because of this tolerance, S. aureus can survive well on salted meat products, such as hams and sausages where other organisms cannot compete. It has been found in open sores on the hands and arms of food service employees. The infective dose of S. aureus is less than 1.0 micrograms of its toxin, and this level is reached when S. aureus population

reaches 100,000 organisms per gram in the food. It can produce its toxin at a water activity as low as 0.86. Also, the toxin produced by S. aureus is extremely heat-stable, and can survive even boiling or retorting temperatures. Therefore, cooking is not a sufficient barrier to eliminate pre-formed toxin in food. In fact, cooking destroys microbes, which would normally compete with S. aureus. The best way to prevent S. aureus is through eliminating hand contact with ready-to-eat foods, restricting employees who have infected sores on their hands and arms, and maintaining proper temperatures.

7.2 EFFECT OF STUFFING

Many meat and poultry products are prepared with stuffing, and the stuffing may have a significant effect on heat penetration. Recipes may call for the addition of raw potentially hazardous foods such as eggs, oysters, and other foods that may introduce high bacterial initial loads. It is always a good recommendation to cook stuffing separately from the meat or poultry. When adding stuffing, close attention must be paid to the required oven temperatures and times to bring the internal temperature to the level necessary to destroy pathogenic organisms in the food. To assure that the proper internal temperature is reached, a thermometer should be used. In order to reach the coldest spot, the temperature probe should be located as near to the geometric center of the mass as possible.

7.3 SIZE AND WEIGHT OF THE FOOD

Weight and shape have a significant effect on the penetration of heat to the coldest spot in the food product. For this reason oven temperatures at which roasts are cooked are based on the weight of the roast. In addition to weight, the size and shape of the food being cooked is also significant. For example, a roast weighing more than 10 pounds, but with its greatest thickness being 4 inches will cook faster than a similar roast having a thickness of 8 inches.

7.4 MICROWAVE COOKING

Most of the same factors that affect traditional cooking also influence microwave cooking. However, the moisture and the salt content of foods being subjected to Microwave cooking play a more important role. This is due to the nature of the electric field involved in causing molecular friction, which is the principle of microwave cooking, and the effect that moisture and salt have on this process. Covering foods during microwave is recommended since this aids in maintaining moisture levels.

Since cold spots will exist in microwave cooking, it is important to measure the internal temperature of the food in multiple sites. Also, it is important during microwave cooking to stir and rotate the food since such actions increase uniformity in cooking by reducing cold spots.

Due to uneven heating of the foods, it is recommended that foods be held for two minutes after the cooking process before serving to allow for thermal equilibration and exposure of pathogens to the heat.

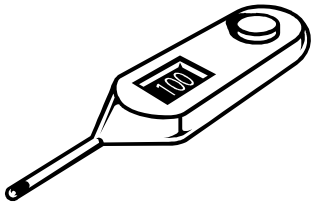
The wattage of microwave ovens varies, and this has a significant effect on the amount of heat generated. For this reason, internal temperatures should be relied upon to assure a proper cook rather than relying on the amount of time specified in recipes.

In a traditional cooking process, the cumulative effects of heating time in the oven contribute to the destruction of pathogens. Oven time includes:

- The time the food is being heated to the cook temperature (come-up).
- Time the food is held at the cook temperature.
- The time during cooling (come-down).

When these cooking processes are developed, the come-up as well as the come-down times are added to the equation. In microwave cooking, the rapid increases in temperature that is achieved results in a cook process that does not include come-up time. Therefore microwave cooking times are calculated differently. To be comparable, the food being subjected to microwave cooking must achieve a comparable internal temperature and hold that temperature for a specified time.

Hot Holding, Cooling, Cold Holding, Reheating, Time As A Public Health Control



Introduction

In this part we will explore the requirements, and the control's necessary for hot holding, cooling, cold holding, reheating, time as a public health control and temperature measuring.

Objective

Upon completion of this part, the participants will:

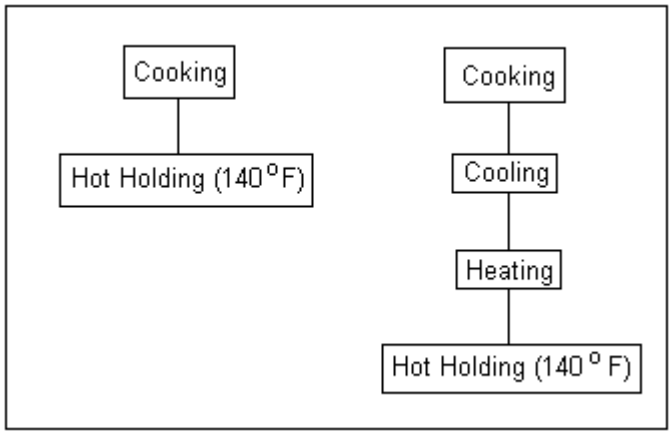
- Understand the concepts and principals of hot holding and the microbiological implications of not maintaining foods at the proper temperatures.
- Understand the reasons and methods for rapid cooling to a safe temperature and the effect of cooling on the growth of microbes.
- Have an understanding of the equipment and methods necessary for proper cold holding, the difference between cold holding and cooling.
- Understand the requirements for reheating.
- Understand the requirements for using time as a public health control.
- Understand various methods of measuring product temperatures.

Hot Holding

Many foods are cooked for immediate consumption. However, some foods may be prepared in advance of service. Not all pathogens are killed during the cooking process, and even if they were, subsequent handling can reintroduce pathogens that may grow in foods if proper temperatures are not maintained. It is critical to either hold these foods at safe elevated temperatures, or rapidly cool to safe cold temperatures. Cooling and cold holding will be discussed later in this module. Let's turn our attention now to the procedures used for and the controls necessary for the hot holding of food products.

Foods may be taken directly from the cooking process to hot holding. In other instances, a food product is cooked, cooled, then reheated and placed into hot holding. It is crucial for holding that the minimum product temperature of 140°F be maintained. The danger during hot holding is that spores of organisms such as C. perfringens will germinate and begin rapidly reproducing.

HOT HOLDING



Food Code Requirements

The FDA Food Code specifies that potentially hazardous foods are to be held at 140°F or above. An exception to this rule is allowed for whole beef roasts and corned beef. It allows a minimum hold temperature of 130°F if they have been cooked or reheated to the temperatures and time specified for these products in the Food Code under Section [3.402.1 1 (13)]. See the following two tables.

OVEN TYPE	OVEN TEMPERATURE BASED ON ROAST WEIGHT	
	Less thank 4.5 kg (10 lbs.)	4.5 kg (10 lbs.) or More
Still Dry	177°C (350°F) or more	121°C (250°F) or more
Convection	163°C (325°F) or more	121°C (250°F) or more
High Humidity[1]	121°C (250°F) or more	121°C (250°F) or more
[1] Relative Humidity greater than 90% for at least 1 hour as measured in the cooking chamber or exit of the oven; or in a moisture-impermeable bag that provides 100% humidity.		

And

All parts of the food must be heated to the temperatures and held for the time that corresponds to that temperature as specified below.

TEMP °C (°F)	TIME[1] IN MINS	TEMP °C (°F)	TIME[1] IN MINS	TEMP °C (°F)	TIME[1] IN MINS
54(130)	121	58(136)	32	(61(142)	8
56(132)	77	59(138)	19	62(144)	5
57(47)	47	60(140)	12	63(145)	3
[1] Holding time may include post-oven heat rise…					

For several reasons, the food manager may wish to hold food products hot enough to serve, but below safe food holding temperatures. An example is maintaining prime ribs at below safe temperatures to assure that they are kept rare. Other reason may include maintaining marginal temperatures to prevent drying of the food, over cooking it, or the development of a film on soups or gravies. It is therefore important to attempt to educate food managers to assure that they understand that it is critical to maintain proper hot hold temperatures. It is important that decisions about holding

temperatures are based on food safety and not on food presentation. If presentation is important, these foods should be prepared for immediate service.

Methods For Hot Holding

There are several methods and types of equipment used in the hot holding of foods. The most common use of hot holding is in the cafeteria style serving of foods. Meats and poultry served from cafeteria or buffet lines can be placed in typical hot hold pans on steam tables, in bain-maries, storage units, etc. Regardless of the method employed, it is important to remember that it is not the thermostat setting of the hot holding equipment, but the temperature of the food that must be controlled. Since there may be varying temperatures in a hot holding unit, moist and dry products may maintain heat differently.

Remember that some of the equipment designed for hot holding of food should not to be used for heating. This equipment is designed to hold temperatures that have already been reached, and may not have sufficient heating capacity to adequately reheat food products that have already been cooled. Cold foods placed in food equipment could remain too long in the temperature danger zone, allowing for the growth of pathogens. Other considerations in hot holding should include:

- The amount of food placed into hot holding equipment must not exceed its capacity.
- The occasional stirring of food in hot hold to assure uniform temperatures. Temperatures in the top of deep containers can cool to favorable growth conditions. Occasional stirring of these containers will promote temperature uniformity.
- There must be safeguards to prevent contamination of the foods from contact with the customers.
- Food temperatures should be monitored in multiple food items at varying food depths.

Freezing

Some microorganisms remain viable for long periods of time during frozen storage. Most viruses, bacteria spores and some bacteria vegetative cells survive freezing unchanged. Some of the other organisms are sensitive to one or more steps associated with the freezing process, that is: freezing, frozen storage, or thawing. Since multi-celled organisms are generally more sensitive to low temperatures than are bacteria; freezing and frozen storage are good methods for destroying organisms such as parasitic protozoa, nematodes and trematodes in various foods. This is especially important if they are eaten raw or under-cooked.

Cooling

The cooling of meat and poultry products is critical for prevention of pathogens. The following sections deal with cooling factors that are important at the retail level.

Purpose Of Cooling

Holding food temperatures above 140°F for extended periods can have an undesirable effect on the quality of foods due to such things as loss of nutrients, flavor changes, and drying of the food. Cooked foods are usually cooled in order to be stored for longer periods at refrigerated temperatures. Refrigerated foods must be held at 41°F or below.

Improper cooling of potentially hazardous foods is consistently identified as a leading cause of confirmed foodborne illnesses in this country. Outbreaks occur because foods can contain spores or be re-contaminated with vegetative cells of pathogens during cooling. Re-contamination occurs through a variety of poor sanitation practices such as hand contact, contact with raw foods, unclean equipment, etc. If such contaminated foods are allowed to stay within the danger zone for extended periods, pathogens can grow to levels sufficient to cause food illness.

Cooling Standard

To assure that potentially hazardous foods are cooled safely through the danger zone, a two-part cooling standard has been developed. They must be cooled from 140°F to 70°F within two hours, and then from 70°F to 41°F within four hours.

Most pathogens' optimal growth temperatures fall between 140°F and 70°F, therefore it is crucial to move the temperatures of foods rapidly through this range. Once this temperature range has been passed, pathogen growth slows, and an additional 4 hours can be taken to finish cooling to 41°F. If a potentially hazardous food has been previously held at temperatures in the danger zone, the time they were held at those temperatures must be accounted for.

You should be aware that this two-part standard may not apply to all foods. The Food Code specifically addresses foods prepared from ingredients held at room temperature, for example, canned chicken. Since the starting temperature of the food is generally around 70°F, they must be cooled to 41°F within four hours. The Food Code also recommends that all ingredients for cold salads be refrigerated prior to assembly.

Factors That Affect Cooling

Cooling of food products is affected by a number of factors, such as the temperature of the food at the start of cooling, its size, density, shape, surface area, and other factors that influence the rate of heat transfer from the food. Remember we discussed heating of foods by conduction, convection and forced convection. These same principles also apply during the transfer of heat out of a food product during cooling. We will discuss the cooling factors Initial temperature, pre-cooling, stirring, use of ice, size and shape, density, and insulation.

a. INITIAL TEMPERATURE

The initial temperature, or IT is a term that refers to the temperature of a product at the beginning of a process. The IT of a food can influence the amount of time necessary to cool the food to a safe temperature. The difference between temperature of the food and its surrounding refrigerator air temperature dramatically affect the cooling rates. At first, when the hot food is exposed to the very cold air in the refrigerator, the rate at which the food is cooled is rapid. However, as the temperature of the food and the air temperature of the refrigerator come closer together, the rate of cooling of the food becomes slower and slower.

In addition, the hot temperature of a food at 140"F may tax the capacity of the refrigerator or cooler. For this reason, very hot products should not be taken from cooking and placed directly in a refrigerator. It is much preferable to pre-cool to a more acceptable temperature before the product is placed in the refrigerator.

b. PRE-COOLING

Adequate refrigeration capacity is essential to proper cold holding. However, a normal commercial refrigerator or walk-in cooler is designed to hold foods at refrigeration temperature rather than provide rapid cooling of large volumes or very hot products. Refrigerators usually need some help to rapidly chill foods, depending on the type, size and temperature of the food to be cooled, and the design and capacity of the refrigerator.

The use of ice baths is an excellent way of reducing the food temperatures to a point where a refrigerator should be able to handle further cooling. For example, a 10 gallon container of thick soup or stew could take more than 24 hours or longer to cool if the hot container was placed in the refrigerator as one unit. By dividing this product into 10-one gallon containers, we reduce the distance that the heat must be transferred through and the time needed to cool the product to a safe temperature can be significantly reduced. However, it may still take longer than the time allowed in the two-part cooling standard if we place the containers of food in the refrigerator while they are still hot. By

placing these one-gallon containers in an ice bath and occasionally stirring the product we can more easily pre-cool the product to 70'F within the required two hours.

The two-hour limit for passing from 140°F to 70°F must be met. If pre-cooling only lowers the temperature to 90°F, and this takes one hour, then the refrigerator must be capable of reducing the temperature from 90°F to 70°F in one hour, and subsequently to 41°F within an additional four hours. Remember that during any precooling steps, products must be protected from contamination.

c. STIRRING

Stirring of the liquid product is critical to assure uniform and overall rapid cooling. Stirring provides a forced convection environment for heat transfer that may not exist. If products are not stirred, the product will continue to have warm spots that can support the germination and growth of microbes such as C. perfringens. This is especially true of thick materials where the development of convection currents is not likely to occur. A food having a thick consistency placed in an ice bath and not stirred can continue to have a temperature above 70°F near its geometric center well beyond the two hours allowed in the standard. In cooling we are concerned about the elimination of hot spots in the product.

d. USE OF ICE, ICE PADDLES, AND METAL PINS

To rapidly reduce the temperature of some products, ice can -be added directly to the product. However, the melting ice may dilute the product, and the food handlers and cooks would need to compensate for the added water in the recipe. Ice paddles can be used to cool the product and avoid the dilution problem. These metal paddles are hollow, allowing ice to be placed in them. Since the metal is an excellent conductor of heat, these paddles are a very effective way of rapidly cooling hot products. However to obtain rapid efficient cooling, the product must be stirred frequently during cooling. Another use of metal to cool a product is metal cooling pins that are inserted into a food item leaving a portion of the pin exposed to cooling air currents. The metal acts as a heat sink and absorbs heat from the food item and subsequently transfers it to the surrounding air.

e. SIZE AND SHAPE

Conduction cooling involves heat transfer out of a solid product from molecule to molecule. The distance from the surface to the center of a food mass influences the rate at which the food cools to a safe temperature. The size and shape of large food masses should be reduced and surface area

increased to improve heat transfer and speed cooling.

Turkeys, hams or roasts should be deboned or cut into slices and then layered not more than a few inches deep for cooling. This decreases the thickness, and increases the surface area exposed to cold air currents, resulting in faster cooling.

Large quantities of foods should be placed in shallow pans for cooling. The depth of the food in these pans should not exceed four inches, and they should be placed to allow the free flow of air around them during cooling.

f. DENSITY

As a general rule, higher density foods contain more water, and since water is an excellent conductor of heat, foods with high water content transfer heat faster. In addition to aiding the removal of heat from solids and semisolids by conduction, when the water content reaches levels that causes the food to be fluid, cooling may be increased due the development of convection currents. For example, a thick mass of turkey dressing, in which cooling is by conduction, will cool much slower than a thin soup stock, where convection currents aid cooling. Stirring this same soup stock will create forced convection currents that will cause faster cooling.

g. INSULATION FACTORS

It is important to recognize the insulating properties of some food containers, and guard against their use during cooling. Stainless steel is an excellent conductor of heat, and food containers of this material will facilitate cooling. Plastic containers do not conduct heat rapidly and can serve to insulate foods against cooling. Covering of food containers also serves as an insulator.

The free movement of air at the surface of a food facilitates rapid cooling. Clear plastic wrap that adheres to the sides of the food container and seals air in, and other covers that tend to insulate the food should be avoided. Since cooling is much faster when a food is uncovered, it is preferable to leave food uncovered unless there is a danger of cross contamination. If covers are needed to prevent contamination from dripping or other contaminants, a loose fitting cover should be applied. An offset lid or aluminum foil, which is tented over the food container, serves to protect the food and allows for free air movement over the surface of the product which promotes cooling. Once a food reaches 41°F, a more secure lid can be used.

Types of Cooling Units

a. REFRIGERATORS AND COOLERS

As mentioned earlier, most refrigerators are designed to keep cold foods cold. They are not designed to quickly cool large volumes of hot foods through the danger zone. Foods can be cooled in refrigerators if proper procedures such as pre-cooling foods described earlier are followed.

There is a variety of cooling units available for use in retail including walk-in coolers, reach-in and pass-through units. A small reach-in or pass-through unit may be all that is needed by a small retail operation. Care should be taken to not over fill these refrigerators beyond their cooling capacity. In addition constant opening of the doors can have a dramatic effect on the units ability to maintain proper temperatures causing undue stress on the cooling unit. This is especially true in pass-through units that have doors on both sides.

Some refrigerators have fans that move the air to improve cooling. Air movement is important to proper cooling, and care should be taken to assure that the manner of storing foods in these refrigerators does not impede this flow of air. Shelving in walk-in coolers is designed to be open to facilitate air movement. Occasionally food managers line these shelves to prevent contamination of foods stored on lower shelves. If you encounter this during your inspection, you should discourage this practice since it can prevent proper air movement and limit the ability to cool foods rapidly.

The adequacy of refrigerators depends on the amount, types, as well as the temperatures of foods being cooled in them. The refrigerator's ambient air temperature is important, however, the significant factors are the temperatures of foods being held in them, and the amount of time a food product remains at temperatures between 140°F and 41°F.

In order to evaluate the adequacy of the refrigerator to adequately cool a food, temperatures must be measured throughout the time it takes to move the food through the danger zone.

b. RAPID CHILLING METHODS

There are pieces of equipment that are designed specifically for rapid chilling of hot foods, for example tumble chillers and blast freezers. While a tumble chiller may not be economical for small operation, they may be found in larger retail facilities that produce large volumes of foods. The basic principle is that uniform size food items are sealed in plastic and then dropped into ice cold water where they are tumbled to chill quickly. Foods can easily pass through the temperature danger zone in these chillers within two hours. Blast freezers are freezers that can also cool foods to safe temperatures very rapidly. There are also rapid chill refrigerators that have large capacity compressors and

fans to blow cold air over the foods to chill them quickly. When shallow pans are used to hold the foods in these refrigerators, temperatures can be lowered rapidly through the danger zone.

Control By Water Activity, Ph, Chemicals, & Packaging

Objectives

At the completion of this module, participants will be able to apply knowledge of the following control methods for pathogenic microbiological growth in food products and in determining the adequacy of controls when conducting inspections.

- Control of pH (acidity)
- Control of Water Activity (a_w)
- Chemical Preservatives
- Control through Packaging

Introduction

The conditions that pathogens need for growth: nutrients; temperature; water activity; pH; inhibitors; and atmosphere. The food manufacturer, handler and retailer can use these limits to control pathogen growth, with one exception, nutrients. Except in limited instances, most foods offer sufficient nutrients for pathogen growth, so there really aren't any defined limits for control. This allows us to concentrate on the other factors that can control growth.

Water activity and pH can be controlled directly in foods. We can create inhibitors to growth by adding chemical additives or substances such as salt. In addition, we can adjust the atmosphere through special packaging techniques. Very often processors use a combination of these controls, rather than relying on only one. This is because a one-control system carried to the extreme, can be harsh, making products unacceptable to consumers. The use of multiple controls is called the hurdle concept.

Microbiological controls using pH, water activity, inhibitors, and atmosphere will be outlined in this section. Temperature controls including refrigeration and thermal processing will be covered later.

pH Control

Every microorganism has a minimum, optimum, and maximum pH for growth. Yeasts and molds can grow at low pH, but 4.6 is generally considered the level that will prevent the growth and toxin production for pathogens - which is what we are primarily concerned about. Keep in mind that some pathogens, and in particular *E. coli* 0157:H7, can survive acidic conditions for extended periods of time, even if their growth is inhibited. pH is considered primarily a means of growth inhibition and not a method for destruction of existing pathogens. However, at low pH values many microbiological organisms will be destroyed if held at that pH for significant time.

A pH 4. 6 is used as a divider between what we call acid and what we call low acid foods. Some foods that start out as a low acid food are processed in such a way that they become an acid food. That will be discussed later.

Naturally acid foods are those that Mother Nature adds the acid to. Examples of naturally acid foods are: Peaches with a pH in the range of 4.0; Orange juice in the range of 3.5; and Apples with a pH in the range of 3.5. In general, most fruits are in this group. However, some tropical fruits including pineapple, may fall in the pH range above 4.6 depending upon growing conditions.

Examples of **low acid foods** (pH above 4.6) are: Fresh fish with a pH in the range of 6.3; Canned green beans with a pH in the range of 5.0; Bread with a pH in the range of 5.5; and Fresh ham with a pH in the range of 6.2. As you can see, low acid foods include protein foods, most vegetables, starch based foods and a variety of others.

Examples of foods that are processed to make them acid include pickled fish and pickled peppers that use vinegar - acetic acid - to lower the pH (a process called acidification); and olives and sweet pickles which use a fermentation process to produce lactic acid which reduces the pH.

Acidification is the direct addition of acid to a low acid food. The target is usually a pH of 4.6 or lower. These foods are called acidified foods and are covered under FDA regulations 21 CFR Part 114. There are instances where the target pH is higher than 4.6 and the food requires multiple barriers, such as refrigeration. These foods are not covered by the acidified food regulation.

Fermentation is a process where certain non-harmful microorganisms are used to promote chemical changes in the food. The action of these microorganisms result in

the production of acid or alcohol. Bacteria typically produce acetic or lactic acid. Yeast typically produce alcohol.

The production of acid or alcohol through fermentation serves two purposes. One is to impart certain qualities to the food to produce a desired taste or even texture. An example of this is yogurt. It gets its unique flavor and texture from the fermentation process. The other purpose is to preserve the food, as with pickled products. These foods are not regulated by the acidified food regulations. However, the food must be fermented to a pH of 4.6 or below to be considered safe at non-refrigerated storage temperatures.

Acidification

Acidification is the direct addition of acid to a low acid food. There are a variety of acids - acetic, lactic, and citric - that can be used depending on the desired attributes of the finished product.

Some other examples of acidified products are: Pickled pig's feet, pickled onions, pickled asparagus, and fresh pack cucumber pickles which are acidified rather than fermented to get the desired pH.

Rather than using acids to acidify foods, naturally acid foods, such as tomatoes, can be added to acidify low acid ingredients. An example is the use of tomatoes in spaghetti sauce containing whole vegetables like celery, onions or peppers. Canned tomatoes generally have a pH of about 4.2, while the other vegetables are low acid. The finished food would be below pH 4.6.

A food is considered to be acidified, and covered by the regulations, if the pH of the finished food differs from the pH of the acid raw material. For example, we know that the raw material tomatoes were 4.2. If the finished product pH was 4.5 then the food would be acidified, because some of the acid from the tomatoes was used to acidify the vegetables. On the other hand, if the finished product pH was still 4.2, then no significant amount of acid from the tomatoes was used to acidify the vegetables. In this case the product might not be covered under the acidified food regulations and may not be considered an acid food by formulation. Some of these products are mustard, catsup, salad dressing and other condiments. - all of which are shelf stable.

Processors of acidified foods are required to register and file a scheduled process with FDA. The process needs to be scientifically established to ensure that the final pH is always below 4.6. Processors need to test each lot of finished product for **equilibrium pH**. That means a natural pH balance has been reached by all ingredients - which can take as long as 10 days in foods with very large particulates. Products that require several days to reach equilibrium pH may need to be refrigerated during that time to prevent the growth of *Clostridium botulinum* or other pathogens. In order to speed up the testing process, the product can be blended to a uniform paste. Where a food that contains oil is blended, the oil should be removed before blending. Another way to do this is to measure the pH before the oil is added to the product since the oil does not affect the final pH.

Measuring pH

If a processor is using acidification, they must have some way to measure pH. The pH meter is what most processors use, but they could use indicator solutions, indicator paper, or titration as long as the finished pH is below 4.6. If a pH meter is used, it must be calibrated properly.

The pH meter can be a two electrode, or a single combination electrode, where both functions are combined into one electrode system. One is the reference electrode and one is the measuring electrode. When not in use, the electrodes are stored submerged in distilled water or other solutions as recommended by the manufacturer. The instrument should be checked each day of use with two different buffer solutions - one on either side of the expected equilibrium pH. After calibration, the electrodes should be rinsed off with distilled water and then they can be used for testing. The operation and calibration of the pH meter should follow the meter manufacturer's instructions.

Direct Acidification & Bath Acidification

There are several different methods of adding the acid to the product. One method is called **direct acidification** where predetermined amounts of acid, and the low-acid foods are added to individual finished product containers during production. With this method, it is important that the processor control the acid to food ratio. This is probably the most common method used for acidified vegetables. Another method of acidification is **batch acidification**. As the name implies, acid and food are combined in large batches and allowed to equilibrate. The acidified food is then packaged.

The necessary frequency of monitoring the finished product for pH would be less for batch acidification than for direct acidification. This is because there is variability from jar to jar with direct acidification that you do not have with batch acidification.

One final point on acidified foods and acid foods by formulation is that they must be heat treated sufficiently to inactive spoilage microorganisms and vegetative pathogens. There are two reasons for this. One reason is to prevent spoilage triggering economic loss, and the other is that the action of the spoilage organisms can raise the pH, compromising the safety of the product.

Additional information can be obtained on acidified foods from FDA's Investigators "Guide to the Inspection of Acidified Food Manufacturers".

Fermentation

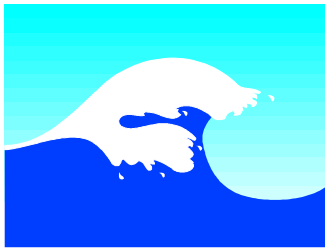
Fermented foods are an area that is very often confusing when trying to determine if a particular food is safe or not. The best way to understand this is to look at examples, two of which have already been mentioned - fermented pickles and yogurt. Here are some others.

In wine and beer, yeast is used to ferment the product to alcohol. The alcohol preserves the product. In the production of sauerkraut, fermented sausages, cheese, sweet pickles, olives, and buttermilk, lactic acid is produced by bacteria during fermentation. Molds are used to ferment some foods such as soy sauce, tamari sauce, and other oriental foods, mainly for taste and other characteristics.

In practice, fermentation is quite an art. You need to encourage growth of the right organisms and discourage the wrong organisms that would cause spoilage. This is usually accomplished by adding salt or a starter culture to the food, or in some cases slightly acidifying it. A starter culture can be either yeast or bacteria.

In many fermented products, there is no process to eliminate the acid-producing bacteria. That is common for many but not all fermented products. It is the reason why most fermented products have to be kept refrigerated - so that the culture bacteria do not spoil the product.

Water Activity Control



Like pH, every organism has a minimum, optimum, and maximum water activity for growth. Yeasts and molds can grow at low water activity, however 0.85 is considered the safe cutoff level for pathogen growth. 0.85 is based on the minimum water activity for *Staphylococcus aureus* toxin production.

Water Activity	**Classification**	**Requirements for Control**
Above 0.85	Moist Foods	Requires refrigeration or another barrier to control the growth of pathogens
0.60 and 0.85	Intermediate Moisture Foods	Does not require refrigeration to control pathogens Limited shelf life because of spoilage, primarily by yeast & mold
Below 0.60	Low Moisture Foods	Extended shelf life, even without refrigeration

Foods above 0.85 water activity require refrigeration or another barrier to control the growth of pathogens. Foods with water activities between 0.60 and 0.85 are classified as intermediate moisture foods. These do not require refrigeration to control pathogens, but have a limited shelf life because of spoilage, primarily by yeast and mold. For the most part, foods with a water activity below 0.60 have an extended shelf life, even without refrigeration. These foods are called low moisture foods.

Some examples of what are called moist foods (those with water activities above 0.85) are:

Moist Foods	Water Activity
fresh salmon	0.99
Apples	0.99
Milk	0.98
cured ham	0.87
Bread	0.95

Most fresh meats, fruits, and vegetables fall into this category. The big surprise here is probably the bread. Most of us tend to think it is a dry, shelf-stable product. Actually, it has a relatively high water activity. It is only safe because of the multiple barriers of pH, water activity, and mold growth, which is favored over pathogen growth. In other words, it turns green before it becomes dangerous.

Some examples of intermediate moisture foods (water activity between 0.60 and 0.85) are:

Intermediate Moisture Foods	Water Activity
molasses	0.76
heavily salted fish such as cod	0.70
Flour	0.70
Jams	0.80
dried fruit	0.70
soy sauce	0.80

Some unique products like soy sauce appear to be a high moisture product, but because salt, sugars or other ingredients bind the moisture, their water activities are quite low. Soy sauce has a water activity of around 0.80. Because jams and jellies have a water activity that will support the growth of yeast and mold, they are mildly heat-treated immediately before packaging, to prevent spoilage.

Some examples of fully shelf stable products, or low moisture foods (water activity below 0.60) include the following:

Low Moisture Foods	Water Activity
dried noodles	0.50
Crackers	0.10

So foods can be placed into three categories, based on their water activity. Some of the intermediate and low water activity foods have naturally low water activity; for example, molasses and flour. Those foods will not be discussed because water activity does not have to be controlled during processing.

Other intermediate and low water activity foods, like dried fruit, salted fish, strawberry jam, crackers, soy sauce, and noodles, start with a high water activity food and through processing, the water activity is reduced.

Control of Water Activity

Some of the products in the group that was discussed require careful control of water activity, while others do not. For example, the jam would not be jam - in other words it would not gel - and could not be marketed unless the sugar needed to reduce the water activity was present. These types of products do not require control of water activity in order to be safe. On the other hand, you could market a more moist dried fruit or less salty fish, which might be unsafe from a water activity standpoint. For that reason, control of water activity is important in these products.

There are two primary ways of reducing water activity in foods, drying and adding salt or sugar to bind the water molecules.

Drying is one of the oldest methods of food preservation. In addition to preservation, drying creates its own characteristics in foods, much as fermentation does. While open air-drying is still practiced in many parts of the world, there are four primary methods of drying in this country:

- Hot air drying - used for solid foods like vegetables, fruit, and fish
- Spray drying - used for liquids and semi-liquids like milk
- Vacuum drying - used for liquids like juice
- Freeze-drying - used for a variety of products.

The other method of reducing water activity in foods is adding salt or sugar. Some examples of these types of foods - soy sauce; jams; and salted fish – have already been discussed. There really is not any very special equipment needed to do this.

For liquid or semi-liquid products, like the soy sauce or jam, the process involves formulation control. For solid foods like fish or cured ham, salt can be applied dry, in a brine solution or brine injected.

There are a couple of approaches to controlling water activity. First, you can accomplish this by having a scientifically established process for drying, salting, or formulation that ensures a water activity of 0.85 or below, and then by closely following that process. Second, you can take finished product samples and test them for water activity.

Chemical Inhibitors

Sometimes the chosen food preservation method does not provide protection against the growth of all microorganisms. In these cases, additional protection may be provided by the addition of chemicals. Chemical preservatives include **benzoates, sorbates, sulfites, nitrites, and antibiotics**. Examples of products that use this method of control include the following:

- Hummus that uses sodium benzoate to inhibit yeast and mold.
- Bread that uses calcium propionate to inhibit mold.
- Smoked fish that uses sodium nitrite and some of the ingredients in the wood smoke to inhibit *Clostridium botulinum.*

Chemical preservatives work through one or more of four actions on microorganisms. They can denature protein, inhibit enzymes, and alter or destroy the cell walls or cell membranes.

Some of the more commonly used chemical preservatives are:

- **Benzoates**, which include benzoic acid, sodium and potassium benzoate, and parabens. They are used primarily to inhibit yeast or mold.
- **Sorbates**: including sorbic acid, and sodium and potassium sorbate. Sorbates are used to inhibit mold.
- **Propionic acid** is used in breads, cakes and cheese to inhibit mold.
- **Sulfites** including sulfur dioxide which are used in a variety of products including lemon juice, seafood, vegetables, molasses, wines, dried fruit and fruit juices. Sulfites are used primarily as an antioxidant but also have antimicrobial properties.
- **Nitrites**, which are used in, cured meats and smoked fish, usually in combination with salt or sugar. Nitrites inhibit the growth of *Clostridium botulinum.*
- **Salt** is also used to prevent the growth of pathogens, especially *Clostridium botulinum.* We have already talked about how salt is used to reduce water activity

in products like salted fish. Salt also has a direct antimicrobial effect in products like smoked fish.

- **Nisin and natamycin** are two antibiotics approved for use directly in food. They are used as antimicrobials in cheese.

These and other chemical preservatives, including the approved uses and use levels, are included in the FDA's Food Additive Status List.

Control for the Use of Chemical Preservatives

The control for the use of chemical preservatives is quite simple, **formulation**. By that, we mean that the processor needs to carefully control the quantity of food additive for each batch of product.

However, in some cases it may not be that simple. Take a product like smoked fish. For safety, this product relies on a certain water phase salt level - the percent salt in the water portion of the fish. The water phase salt level that you need to control *Clostridium botulinum* is not usually achieved by just formulation. It requires a combination of factors such as brining time, brine strength, drying time and temperature. Just like in water activity, processing conditions need to be scientifically established and followed. An alternate or duel approach for control is to test the finished product for water phase salt.

Packaging

Packaging is different from the other methods of control. Although packaging is sometimes used to control microbiological growth, it is limited to the control of spoilage organisms. Packaging is not considered a method for controlling the growth of pathogens. In fact, packaging contributes to product safety concerns, which is what we are going to concentrate on here.

From a food safety standpoint, packaging serves two functions; it prevents contamination of the food, and makes possible, or extends the effectiveness of food preservation methods. For example, packaging maintains the atmosphere in a controlled or modified atmosphere package or a vacuum package, or it prevents rehydration of a dried food.

Types of Packaging

Vacuum Packaging

A number of products such as smoked fish are vacuum packaged. Vacuum packaging is where air is mechanically extracted from the package immediately prior to sealing. The product is placed in a low oxygen permeable bag. The bag is placed in the vacuum machine where air is mechanically evacuated from the package and a heat seal is formed. The film is held tight against the product. There is no air or atmosphere left in the package. Vacuum packaging machines were traditionally only found in the food manufacturing arena. Today, however, we find them in places like hospital kitchens and retail food stores.

Modified Atmosphere Packaging

Products such as fresh pasta can be packaged in a modified atmosphere package. Modified atmosphere packaging involves a one-time gas flushing and sealing process. Primarily, three different gasses are used for flushing, either singularly or in combination: nitrogen, carbon dioxide, and oxygen. Each one of these gases has a different function.

Nitrogen takes the place of oxygen and therefore reduces the growth of aerobic spoilage organisms.

Carbon dioxide is lethal to many microorganisms and is used to extend shelf life by destroying spoilage organisms.

Oxygen is the lifeline for aerobic spoilage organisms. However, its presence even at reduced levels gives some added safety by inhibiting *Clostridium botulinum.* Striking the right balance between safety concerns and extended shelf life is the trick. Usually, that is at levels of around 2 to 4% oxygen. However, the oxygen present in the package can be depleted by the growth of spoilage organisms that reduce the level below the 2% safety level. For this reason, these products should have a “use-by” date.

Controlled Atmosphere Packaging

Controlled atmosphere packaging is an active system that retains the atmosphere in the package throughout its shelf life by using an oxygen scavenger in the packaging. Beef jerky is an example of this type of packaging. A packet containing iron filings that absorbs oxygen from the package is part of the packaging. Oxygen absorption is useful for extended shelf life products, because most packaging is somewhat permeable to oxygen.

There are a variety of packaging films that provide different rates of **oxygen permeability**. One place that these are used is in the extended shelf life storage of produce. This type of packaging is used for vegetables such as lettuce. When plant materials respire, they take in oxygen and give off carbon dioxide. If the amount of available oxygen is limited by the film you can reduce the respiration rate and extend the shelf life.

An interesting side note is that you do not even need special packaging to reduce the available oxygen and create an anaerobic environment. Packing products in oil, like garlic in oil, can create that same environment.

Reduced Oxygen Packaging

All of these different packaging forms are grouped into a category that we call **reduced oxygen packaging**. The reasons we use reduced oxygen packaging are to prevent the growth of spoilage organisms, thereby extending the shelf life of the product. There are some other product quality benefits as well, such as reductions in rancidity, shrinkage and color loss.

There are concerns with the use of these packages. The extended shelf life provides more time for toxin production or pathogen growth. Lower oxygen levels favor the facultative and anaerobic pathogens over the aerobic spoilage

organisms. For this reason, you may get toxin production before you get spoilage - something that is less likely to happen in traditional packaging.

Clostridium botulinum

The major concern is *Clostridium botulinum,* although there is some reason for concern with other pathogens. With that in mind, these packaging techniques should not be used unless barriers for *Clostridium botulinum* are present. These barriers include: water activity below 0.93 with adequate refrigeration to control other pathogens; pH below 4.6; 10% water phase salt; high levels of competing microorganisms; thermal processing in the final container, and freezing with frozen storage and distribution. Each of these barriers by itself can be effective in the control of *Clostridium botulinum* growth.

Vacuum packaged raw meat and poultry, as well as fermented cheeses, are examples of products where competing microorganisms are used to inhibit *Clostridium botulinum* toxin development. With fermented products like the cheese, the live starter culture proliferates during temperature abuse producing acid that prevents the growth of *Clostridium botulinum*. Vacuum packaged raw fish, on the other hand, is not safe under refrigeration because it may contain type E *Clostridium botulinum* spores that are not controlled by refrigerated temperatures.

Typically products are thermally processed in metal cans, but can also be thermally processed in a glass jar or flexible, retortable pouch. These are shelf-stable products. The problem here is that the flexible retort package looks just like some flexible pouch packaged smoked fish that requires refrigeration. This can make it confusing for consumers and retailers, which is why we sometimes find vacuum packed smoked fish that requires refrigeration on store shelves.

One barrier that was not previously mention as a singular barrier is refrigeration. That is because it is a weak barrier. Temperatures in retail and home refrigerators often do not control temperatures adequately to prevent *Clostridium botulinum* growth. Sous vide foods, which are vacuum packed, partially cooked, refrigerated foods, do rely on refrigeration as a single barrier. Because of this, refrigeration must be tightly controlled throughout processing, storage and distribution in order for this product to be safe. Foods for institutional use may be the only acceptable use of this processing technique.

Earlier, we mentioned the **hurdle concept** or the use of multiple barriers. The hurdle concept is frequently used to control *Clostridium botulinum* growth in reduced atmosphere packages. We mentioned some of these barriers when we were discussing the controls for *Clostridium botulinum*. Just to refresh your memory, some examples of these products are:

- Vacuum packaged, hot smoked fish that uses salt, nitrites, heat damage, and smoke to control type E *Clostridium botulinum* and refrigeration to control type A *Clostridium botulinum*. Guidance materials such as FDA s Fish and Fishery Products Hazards and Controls Guide recommend time, temperature, and salinity levels for smoked fish.
- Cold cut meats that rely on both nitrites and refrigeration to prevent *Clostridium botulinum* growth.
- Canned pasteurized blue crabmeat that has been vacuum packaged. The process for the pasteurized crabmeat uses heat to destroy type E *Clostridium botulinum* and refrigeration to control type A *Clostridium botulinum*.

These products are safe because of their established barriers. Controls for all of these barrier systems have been outlined with the exception of refrigeration and thermal processing. These will be covered in the next two modules.

Thermometers And Their Use

Throughout this discussion we have emphasized the use of temperatures as a control to prevent the unwanted growth of pathogenic microorganisms in our food supply, and we have discussed the need to monitor temperature in these products. There are a variety of different types of temperature measuring devices, and we will discuss their use and limitations in this section. The measuring devices that will be discussed are the mercury-in-glass thermometer, the bi-metallic metal stem thermometer, the digital thermometer, the maximum indicating thermometer, a thermocouple, infrared thermometer, and recording thermometer.

Although we will not discuss the calibration of thermometers, it is important to understand that to assure accuracy, thermometers should routinely be calibrated to a known temperature. Each thermometer should be marked to show the last calibration date, and written standard operating procedures should establish the maximum time a thermometer can be used before re-calibration.

Each type of thermometer has features that make it the most ideal tool to obtain needed temperature measurements. It important to know the features of each type of thermometer, so you can use the appropriate tool for the job at hand.

Type Of Thermometers

Mercury-In-Glass

Mercury-in-glass thermometers are usually accurate and reliable. However because of possible breakage, care must be exercised in their use around unprotected foods. For this reason their use in retail food establishment is limited.

Bimetallic Stem Thermometers

A bimetallic metal stem thermometer is commonly referred to as a dial thermometer, and it is the most frequently seen thermometer in use in the food industry. It is about 5 inches long, and usually there is a dimple near the end of the stem. They contain a coiled helix that expands and contracts in reaction to temperature changes, and therefore are slower to react than digital thermometers. These thermometers are -intended to take temperatures of relatively thick foods. To get an accurate reading, the metal stem must be inserted several inches into the food and left in there for at least 20 seconds. More time is needed for particulady cold foods. The dial thermometer is usually accurate to plus or minus 2°F. Due to the size of the probe, they are not recommended for measuring the temperatures of thin products such as a hamburger patties, or small amounts of food.

Digital Thermometers

Digital thermometers have a wide spread use in the food industry. Their advantage is that they read temperatures rapidly, and they can be fitted with various size probes for specialized purposes such as a thin probe to measure the temperatures of small food items. Their disadvantage is that they can not be calibrated in the field, but must be sent to the manufacturer for this purpose.

Maximum Indicating Thermometers

The maximum indicating thermometer is used to record the maximum temperature that is reached in a food or a process such as the final rinse in a dish washing machine. An example of a maximum indicating thermometer that we are all familiar with is the fever thermometer. These thermometers are very good in indicating the hottest temperature of a food or food process, however they do not provide information about how long that maximum temperature was maintained.

Thermocouples

The thermocouple is an electronic device, and may have one or several temperature sensing probes to measure temperatures at several locations at the same time. Thermocouples measure the electric potential at the point where two dissimilar metals touch. They give faster reaction to temperature changes and provide immediate read-out of temperatures, which can be recorded.

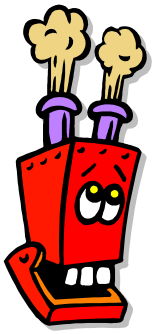
Infrared Thermometers

The infrared thermometer is a new device that can read the temperature of a food without touching it. The device is simply pointed at the food and the surface temperature is read. It has the advantage of fast read-out, and since it does not touch the product, there is no problem with contamination of the food from taking the temperature, and the device does not have to be cleaned between temperature reading of different foods. The major disadvantage is that the device reads only the surface temperature, and this limits its use in retail foods.

Recording Thermometer

The recording thermometer is used extensively to keep a permanent record of temperature during processes. In retail, the most common place to see this type of thermometer is as a recorder of refrigeration temperatures. In the food processing industry, these devices are widely used to record the temperature of various heat treatment processes such as internal temperatures of cooked roast beef.

Food Processing



This section describes different types of heating methods: blanching, cooking, pasteurizing, retorting, and hot holding. Each one has its objective and own specialized equipment and will be discussed individually.

Blanching

- Remove gases
- Soften product
- Fix colors
- Inactivate enzymes
- Inactivate microorganisms

Blanching is a relatively mild heat treatment that is usually performed to improve the quality of preserved or stored food products. It is used to remove trapped gases from the product, soften the product, fix product color, or inactivate enzymes.

It also has the effect of eliminating or reducing the numbers of relatively heat-sensitive pathogens and spoilage organisms.

Water and steam blanchers are the most commonly used in the food processing industry. They are similar in construction and in the way they operate. Product is moved through either a water bath or a steam-filled chamber by either a belt or a screw-type auger. The water can be heated either by directly injecting steam into the water or by running steam through a jacket that surrounds the water bath.

Control of the blanching time and temperature are not usually critical to the safety of the product. One exception would be where a blancher is used to prepare a product for a later heat treatment, such as retorting. Sometimes retort processes are based on changes that are made to the product by the blancher, for example softness or hydration. If blanching is not controlled in these cases, the process may by inadequate. Blanchers should be operated at 180°F or higher or emptied and cleaned frequently to prevent the growth of thermophilic organisms.

Control instruments are pretty simple, usually an indicating thermometer in the water bath or in the live steam. If small temperature fluctuations are important, the indicating thermometer may be replaced with or accompanied by a controller/recorder thermometer.

Since most commercial blanchers are a continuous operation where product enters, moves through, and then exits, the time of the blanch is controlled by determining how fast the product moves through the equipment. That can be checked by timing a block as it enters and leaves. It can also be checked by timing the revolutions per minute of the auger or drive wheel, and applying a little bit of math.

There are some blanchers that operate on a batch basis, where a basket of product is lowered into a tank of hot water. Some blanchers also use hot air or microwaves, rather than hot water or steam, to heat the product.

Pasteurization

Pasteurization is usually designed to eliminate vegetative pathogens, especially those that can grow under normal storage conditions. It is also used to reduce the number of spoilage organisms in order to provide for a reasonable shelf-life. But, in some applications the term can have a somewhat different meaning, which we will cover later. In any case, the process is usually performed at temperatures below the boiling point. Some examples are:

Pasteurized milk. The process is designed to inactivate a relatively heat-stable vegetative pathogen called *Coxiella burnetii*, but it is also sufficient to eliminate *Listeria monocytogenes,* probably the toughest non-spore forming pathogen. Pasteurized milk is distributed refrigerated and is not vacuum packaged. Therefore, spore-forming pathogens that require temperatures of 50^{oF} or above, or anaerobic conditions, such as *C.perfringens*, *C. botulinum*, and *B cereus*, are not targeted by the pasteurization process.

Pasteurized crabmeat. Here the process is designed to destroy the spores of *C. botulinum* type E. By targeting *C. botulinum type* E, the process eliminates all the vegetative pathogens. However, *C. botulinum* type A is unharmed, because it is more heat tolerant. Refrigerated storage controls *C. botulinum* type A, because it will not grow below 50°F.

In a similar product, pasteurized lobster meat, the process is designed to destroy *Listeria monocytogenes*. This process is not adequate to eliminate *C. botulinum* type E, so the product can only be safely distributed frozen. Remember *C. botulinum* type E can grow under refrigeration temperatures above 38°F.

Acid products, such as fruit juices, and products high in sugar, such as fruit preserves are frequently pasteurized to eliminate yeasts and molds that would otherwise grow and result in spoilage. This is not necessarily a safety issue, but certainly an economic issue to the processor. Remember, these products are generally shelf-stable, and that pathogen growth is prevented by the acid and/or sugar content of the food.

Some of these products are not pasteurized to kill yeasts and molds and instead are sold refrigerated. Recent problems with pathogenic *E. coli* in unpasteurized apple juice have changed how we think about the significance of hazards in these and similar products. No longer are we just concerned with pathogens that may grow out during storage and distribution. We are also concerned with pathogens that may be simply harbored by the product. Therefore, these products should be pasteurized using a process that targets *E. coli*.

Pasteurized oysters is an unusual product. It is marketed for people who have health conditions that predispose them to food-borne infections, especially *Vibrio vulnificus*, which often leads to death. This process targets *Vibrio vulnificus*, which is a very heat sensitive pathogen. That means that most other pathogens, and many spoilage organisms are left unharmed. The package is not hermetically sealed, so *C. botulinum* is not a hazard. Shucked oysters have long been distributed refrigerated, and have a relatively short shelf-life. Because the product is raw, spoilage organisms tend to be present in sufficient numbers to dramatically out compete the pathogens. This results in a product that spoils before it becomes unsafe. The pasteurization process is very mild and leaves the product raw, with the spoilage organisms mostly intact. The spoilage organisms and refrigeration serve as the barriers to pathogen growth.

Some pasteurization systems are designed to handle fluid products, like milk and juice, and others are designed to handle solid products, like seafood. Within both groups, some are designed for batch processes and others are designed for continuous processes.

Vat pasteurizer

A vat pasteurizer is used for batch pasteurization of fluids, especially milk products. It is a jacketed tank with steam introduced between the walls of the jacket. In the case of milk pasteurization, the air space above the milk is heated as needed to ensure that any foamed product is adequately pasteurized. The tank must be agitated, resulting in forced convection heating. This is to ensure that every particle of milk receives the required process. There are also a variety of very specific requirements to ensure that there are no dead spaces where milk can get trapped and not receive the required process, such at the outlet valve.

Vat pasteurization of milk products is called a low temperature long time process - for 30 min. at from 145 to 165°F, depending upon the fat content. To ensure that this minimum process is achieved, the vat must be equipped with both an indicating and recording thermometer in the fluid milk, and an indicating thermometer in the air space above the milk. Of course, nothing can enter the vat after the pasteurization process has begun. The vat pasteurizer is limited in the volume of product that it can handle and it is quite energy inefficient. For this reason, most processors of fluid products use a continuous pasteurizer, called a plate heat exchanger.

Typically a plate heat exchanger is used for pasteurizing fluid milk. For ordinary milk it must be able to deliver a process of 161°F for 15 seconds to every particle of milk. The process varies for other milk products.

The milk enters the processing system from the raw milk storage tanks. It is temporarily held in a surge tank, which maintains a constant reservoir of raw milk for the process. The surge tank must be the low point in the system, so that, in the event of a power outage, all raw milk will drain back into the tank, to be processed when service resumes. The milk is drawn from the surge tank by a small booster pump, usually a centrifugal type pump that can't develop much pressure. The milk moves into the regeneration section of the plate heat exchanger, where it picks up heat from milk that has already been pasteurized. The raw and pasteurized milk are separated by thin stainless steel plates. The warmed, raw milk is picked up by the timing pump, which has been calibrated and sealed so that it will always deliver milk at a predetermined flow rate. The timing pump must be a positive displacement pump, and it may also serve as a homogenizer. The timing pump forces milk through the heating section of the plate heat exchanger. Here the milk picks up more heat from steam or hot water which passes on the opposite sides of the stainless steel plates. By the time the milk leaves the heating section it has reached a temperature slightly higher than the desired pasteurization temperature. The milk then enters the holding tube, which is a continuously upward sloping pipe. At the preset timing pump speed, it takes the entire length of the scheduled process for milk to flow the length of the holding tube. The temperature of the milk is sensed at the end of the tube. If the thermometer at the end of the tube registers at or above the pasteurization temperature, you can be assured that the milk was at or above that temperature for the length of the pasteurization process. This only works if no heat is applied to the holding tube. The holding tube must slope upward so that air bubbles don't form. If they did, they would restrict the diameter of the tube, and increase the flow rate, which would shorten the process.

In addition to the indicating thermometer, a recorder/controller senses the temperature, records it, and controls what is called a flow diversion valve. This valve will remain open only if the temperature remains at or above the preset minimum. If the minimum temperature is not met, the valve closes, forcing the improperly pasteurized milk to return to the surge tank. The position of the flow diversion valve (open or closed) is automatically recorded on the temperature recording chart.

Pasteurized milk, which is still under pressure from the timing pump, then moves through the regeneration side of the plate heat exchanger. Here it gives up some of

its heat to the raw milk, which is separated from the pasteurized milk by stainless steel plates. These plates are thin and are subject to pinholes, so the pasteurized milk must always be under greater pressure than the raw milk. That way any leakage through the plates will be from the pasteurized side to the raw side. This pressure differential is assured by placing the timing pump after the raw side of the regeneration section. That way, it draws out the raw milk and pushes on the pasteurized milk.

The booster pump which is located before the raw side of the regeneration section must be relatively small and must be of the type that will slip if there is sufficient back pressure, like a centrifugal pump. That way it can't develop much pressure. Also if a booster pump is used, there must be a pressure sensor and gauge on the entrance end of the raw side of the regeneration section and one at the exit end of the pasteurized side of the regeneration section. There must be greater pressure on the pasteurized side than on the raw side. If not, the sensor must trigger the booster pump to shut off. Timing pump failure or flow diversion valve closure must also cause the booster pump to shut off, because in these situations, there is no pressure being exerted on the pasteurized side.

After the milk leaves the regeneration section it enters the cooling section of the plate heat exchanger. Here, chilled water is on the other side of the plates, and chills the milk down to the desired storage temperature. Finally, the milk moves to the pasteurized milk storage tanks. There must be an air break on this line that is the highest point in the system. That further ensures that there is positive pressure on the pasteurized milk.

There are several other types of pasteurizers that are used for liquid or semi-liquid products: tubular heat exchangers, swept surface heat exchangers, and direct steam injection. Each have their benefits and drawbacks. The tubular heat exchanger, swept surface heat exchanger, and plate heat exchanger can all be used for heating and cooling product.

Tubular heat exchanger.

In the tubular heat exchanger, the product passes through a tube, which is contained within a shell (or a second tube). Between the tube and the shell, hot water or steam moves countercurrent to the product. Flow rate, the length of the tube, the temperature of the heating medium, and characteristics of the product itself are the factors that affect the amount of heat transferred to the product. These heat exchangers are typically used for pasteurization of flavored dairy products and high pulp fruit juices, products that would normally foul a plate heat exchanger.

Some products, like cheese sauces, puddings, margarine, and peanut butter are too viscous for the tubular heat exchanger. So a variation, the **swept surface or scraped surface heat exchanger** is used.

Swept surface or scraped surface heat exchanger

In this system, the heat exchanger is still a tube within a tube. But, a revolving scrapper is fitted into the inner tube to continually sweep the inner wall of the product tube. This facilitates rapid, uniform heating and minimizes product scorching. Control factors are similar to those of the tubular heat exchanger, except that the speed of the scraper also affects the heating rate.

Direct steam injection pasteurizer

As the name implies, steam is injected directly into the product flow to increase its temperature. With this type of heating the formula for the product must be adjusted to account for the water added by the steam or some method must be used to remove the added water.

A number of the products that we talked about earlier are **pasteurized in their finished product containers**. This kind of pasteurization may be done in a water bath, a water spray, or a steam environment.

For example, pasteurization of picked crabmeat in the final container using a typical batch type pasteurization system. The process normally uses two large vats of water; one for heating and the other for cooling the containers of product.

Cans of crabmeat are processed in hot water at 185-200°F using a scientifically established process - a set number of minutes at a set temperature. The process is designed to deliver an internal temperature at the center of the can that is normally at least a 12D process for the spores of *Clostridium botulinum* type E. The first tank is simply a hot water bath that is heated by direct steam injection. It could also be a steam-jacketed kettle. Crates containing the cans of crabmeat are lowered into the preheated water, the water is reheated to the process temperature, and the timer is started. Vigorous agitation through the addition of air to the steam spreader or by water pumps is often needed to ensure that the temperature distribution within the bath is uniform.

Since this process is not effective in eliminating *Clostridium botulinum* type A and some types of spoilage microorganisms, the processor needs to chill the product below the temperature that will support *Clostridium botulinum* type A and other surviving microorganisms as rapidly as possible after the pasteurization cycle is completed. The ice bath or chilled water in the second tank is used for that purpose. The product is normally stored at 38°F or lower to provide a second barrier to the growth of *Clostridium botulinum* type E.

Proper controls for this process include both an indicating and a recorder thermometer in the hot water bath and a clock for timing the process.

One difference with this system is that the temperature of the water is monitored instead of the temperature of the product, as with other systems we have discussed. To design the process a study must be done to correlate water bath time and

temperature to product time and temperature at the cold spot in the can. That will be discussed in more detail later in this module.

An important point, though, is that checking the internal temperature of one or two containers in a hot water bath for each cycle is not an adequate substitute for controlling the water bath temperature. That is because there are usually significant differences in the rates of heating from container to container, as a result of the fill of container, the initial temperature of the product, and other factors. Internal temperature checks are better used as a verification process than a monitoring process.

The **continuous pasteurization system** works well for pasteurizing many products, such as fermented pickles, beer, fruit juices and acidified products, in their finished product containers. In this system, the containers are fed through the pasteurizer on a continuous belt. The containers are gradually heated by steam or hot water sprays and then cooled with water sprays. The pasteurizer contains a series of heating and cooling chambers, each with its own controls. The length of the process is determined by the belt speed. The temperature of the water spray or steam environment is monitored, rather than the temperature of the product. It is important to ensure that water sprays are working properly so that even heating is provided to all containers.

Retorting

The final type of heat processing that will be outlined is retorting or canning. Retorting is a very severe process, performed at temperatures well in excess of the boiling point, usually at temperatures around 250^{o}F. To get to that temperature, steam or water must be under a great deal of pressure. 15 pounds per square inch above atmospheric pressure for 250^{o}F.

That is where the retort comes in. A retort is simply a vessel that is capable of withstanding extreme pressures. It is essentially a pressure cooker or autoclave.

The objective of retorting is to produce a commercially sterile food. That is a state where all pathogens and nonpathogens that could grow during the normal, unrefrigerated storage of the finished product have been eliminated. Even though retorting processes are designed to achieve commercial sterility, thermophilic spoilage organisms can survive the process. However that is more of an economic issue to the processor than a public health issue. We should be more concerned with a minimum thermal process that controls pathogens that could grow out during unrefrigerated storage But even that is not easily achieved. The spores of *C. botulinum* type A are normally the target organism, since they are the most durable form of any food-borne pathogen.

Delivering an adequate thermal process is only half of the battle. The other half is packaging. The product must be packaged so that the food is not recontaminated after the thermal process. The package must have what is called a hermetic seal.

The seam on a metal can, the lid on a glass jar, and the heat-fused seal of a plastic pouch are examples of hermetic seals.

The retorting process takes place after the product has been placed in the container and hermetically sealed. The containers are placed in the retort and the heating medium is introduced, around the containers.

Steam under pressure is the most common heating medium, but superheated water under pressure, or a combination of steam and air is also used. Because it is the most common, steam will be used for an example.

Heat is transferred from the steam to the container and then to the product. The containers are held for the desired length of time in the steam environment. After that, they may be cooled with water, either by flooding the retort or by moving the containers to a water-filled vat, called a cooling canal, or the containers can be air-cooled.

The most important factors to consider in retorting are: determining how much heat is required to inactivate *C. botulinum*. in the food that is being processed - this requires a **heat resistance study**; determining how fast the coldest point in the containers heats - this is addressed by performing a **heat penetration study**; and, ensuring that every container of product is exposed to the processing media (steam, water or steam/air) at the desired temperature - this is addressed by performing a **temperature distribution study**.

All of these steps are part of the **process establishment**. The first step of process establishment is to determine the heat resistance of the pathogen of interest. Fortunately many studies of some of the most significant pathogens, such as *C. botulinum*. have already been done. But, the food itself may affect the rate at which the pathogen is destroyed and additional studies may be required for new or unusual products.

These studies can be performed using a thermoresistometer, a thermal death time retort, or an oil bath. When using the thermoresistometer, a small disk, containing product and a known inoculum of the targeted pathogen , is cranked into a miniature steam chamber. It is held for the desired period of time, and then cranked out of the steam chamber and into a tube of culture media. The tubes are incubated to determine whether the process was sufficient to destroy the inoculum.

When the thermal death time retort is used, miniaturized cans of product and a known inoculum are placed in a miniaturized retort. The cans are subjected to the desired steam temperature for the desired period of time and are then water-cooled. The entire can is then incubated and the number of swollen cans at each exposure time/temperature are determined.

The heat resistance of the target microorganism can also be determined by using test tubes filled with a known inoculum. The test tubes are heated by rapidly placing the tubes into an oil bath at a set temperature and then rapidly cooling the tubes. These test tubes are then incubated and the results of growth are recorded for each time/temperature combination tested.

Many commercial processes are established using a spoilage organism that has a heat resistance greater than *C. botulinum*. This is done not only to establish a very conservative process for *C. botulinum*, but to prevent accidents while working with a known pathogen, and to establish a process which will destroy those spoilage organisms capable of growing at normal storage temperatures.

The time that it takes the product to heat up or cool down using any of these systems is so small that it does not affect the accuracy of the studies. Because of the small size of the disk, can, or tube of food, it almost instantly reaches the desired test temperature. Cooling of the food is also almost instantaneous.

By repeating these studies at various process times at the same temperature, we can establish the D value at that temperature. By repeating the entire study at various temperatures, we can establish the z value. Now we have a picture of the heat resistance of the pathogen in the food of interest.

Lethal Rates of C*. botulinum*

Using a z of 18°F and a Reference

Temperature of 250°F

^{o}F	LETHAL RATE (f_o/min.)
212	.008
221	.024
230	.077
239	.246
248	.774
250	1.000
257	2.45
260	3.60

Several new terms such as D value and Z value were previously mentioned, and there is another important term that needs to be introduced; lethal rate. Remember, the z value lets you convert the lethality of one minute at any temperature to its equivalent lethality at a reference temperature, and that by adding all those lethality's for a process you get the F value. With canning, we are always concerned with *C. botulinum.* By convention we use a z of 18^{o}F and a reference temperature of 250^{o}F. This allows a quick way to convert product temperatures during a process to the reference temperature. It is called the lethal rate. The lethal rate for a temperature is the number of minutes at 250^{o}F that it is equivalent to - its part of an F_o. The lethal rate for 250°F is 1. One minute at 239 is 1/4 as lethal as one minute at 250°F, and one minute at 257°F is about 2 1/2 times as lethal. This way you can quickly add up the total lethality of any process, and express it as the F_o of the process. Lethal rate

tables for a number of z values and reference temperatures exist for many different organisms.

The next step in establishing the process is to determine how the food of interest heats, when packaged, as it will be sold. This will give us a heating profile so that we can use the lethal rates to determine the sterilizing value. This is called a heat penetration study.

The heat penetration study is performed by filling finished product containers of the same dimensions with the food as it will be commercially packaged. It is important that the product represent the worst case heating conditions that are likely to exist commercially; the largest chunks of food, the most viscous sauce, the lowest initial product temperature, the highest filling weight, etc. The study will not be valid for any conditions that are more restrictive to heating than those that were studied. Thermocouples - miniature temperature sensing devices - are placed into a number of cans of the product and connected to a recording device. The thermocouples are placed at the slowest heating spot in the can. The slowest heating spot varies depending upon whether the product heats by conduction or by convection. For a product with large particles, the slowest heating spot will likely be at the center of one of the particles at the cold spot in the can. The cans are placed in a retort, usually a smaller pilot plant size unit where temperature within the retort can be carefully controlled. The retort is operated as it would be commercially and the thermocouples produce a recording of temperature over the length of the process.

The data from the slowest heating thermocouple is used to calculate the F_o. The calculation can be done by using the lethal rate table and adding up the lethal rates for each one-minute period. We assume that the temperature was the same for the entire one-minute period. Of course, it actually is not. In practice, these calculations are performed using rather complex formulas that have the effect of integrating the lethal rates throughout the process. The calculations are normally performed by the data gathering equipment using computers.

In order to achieve a 12D process for *C. botulinum* - the minimum thermal process - we need to achieve an F_o of at least 2.5 min. For commercial sterility, generally we need an F_o greater than this, since many of the spoilage organisms are even more heat resistant than *C. botulinum*.

Remember, the heat penetration study is applicable only to the conditions that were tested in the study. A number of conditions can dramatically affect the lethality of the process. They include:

Factors That Affect Heat Penetration

Initial temperature

Type of heating medium

Fill of container

Viscosity of product

Proportion of solids to liquid

Method of product preparation

Kind, size and arrangement of particles

Position of container in the retort

Vacuum and headspace in vacuum packaged product

Size and shape of container

Headspace in agitated thermal processes

Initial temperature or IT: the lower the IT the slower the can will heat**. Type of heating medium**: steam, water and steam-air release heat to the container at different rates**. Fill of container**: more product in a container may cause it to heat slower. In some cases (such as cooked hams, whole chickens etc.) the product must touch the sides of the container to heat properly. Viscosity of product: the thicker the product the slower it heats because it slows down convection currents. **Proportion of solids to liquid**: the more solids the slower the product heats for the same reason. **Method of product preparation**: over blanching some products can cause them to pack tightly, slowing heating, under blanching others can cause them to be poorly hydrated, also slowing heating**. Kind, size and arrangement of particles**: the bigger the particle the slower the heating, if the particles are arranged in a way that they interrupt the convection currents heating is slowed. **Position of container in the retort**: this can also influence convection currents in some products. **Vacuum and headspace** in vacuum packaged product. Headspace is the room in the can above the product - reducing either vacuum or headspace may reduce the rate of heating. **Size and shape of container**: the larger the container the slower the heating, especially for conduction heating products. Container shape can also affect convection currents. **Headspace in agitated thermal processes**: the smaller the head space the slower the heating, because of a smaller headspace bubble, which causes agitation by moving through the product.

Heat penetration is often confirmed by inoculated pack studies. In these studies a non-pathogen with a heat resistance greater than *C. botulinum* is inoculated into

container of the product, which are then subjected to a commercial process. The cans are then incubated and observed for spoilage.

Thermal processes may also be established using scientific methods other than those described in this module. Some products require special methods to establish the process. These methods are discussed in additional detail in FDA's Guide to Inspections of Manufacturers of Low Acid Canned Foods Parts 1 and 2.

Temperature Distribution

The final challenge is making sure that all product in a retort receives the desired thermal process. This seems like it should be a matter of checking the thermometer to be sure that the retort has reached the process temperature and then timing the process. However, often air can get trapped in a retort and affect the heating of some of the product - envision a bubble of relatively cool air moving around in the retort during the process.

Adequate air removal and uniform temperatures throughout the retort are confirmed by what is called a temperature distribution study.

Temperature distribution studies are conducted by placing thermocouples on the outside of containers throughout the retort in the live steam or other heating media. The retort is operated normally and the temperature changes at each location are automatically recorded. In a properly designed process, all thermocouples will be at or above the temperature displayed by the retort's mercury in glass thermometer by the time that the MIG reaches processing temperature or at least by the time that the scheduled process timing begins.

In a poorly designed system, the temperature at several points in the retort may not reach process temperature until well after the process has begun. In a steam retort this is a symptom of entrapped air. In other water or steam air retorts this usually indicates poor circulation of the heating media. Poor temperature distribution can lead to under-processed product, since some containers will not be exposed to the correct process temperature for the required time.

Steam retorts are vented prior to beginning the thermal process to remove air from the retort. The vent is controlled by a large valve (normally 1 to 3 inches in size) that allows air to escape as steam enters the retort through a separate valve, at the start of the process. The vent valve is usually closed after several minutes to conserve steam. One of the main objectives of the temperature distribution study in steam retorts is to determine the necessary length of the vent cycle. Much smaller openings, (1/16 to 1/8 inches in size) called bleeders provide for circulation of the steam in the retort and continue to bleed away entrapped air from the retort during the process.

Adequate temperature distribution is also influenced by the type, size, and number of cans, design of the retort crates that are used to hold the cans, and design of the divider plates used between the layers of containers. The worst case test used to

establish venting for steam retorts is a cold retort filled with small, water-filled cans, since this condition serves as a large heat sink, causing large quantities of steam to condense and reducing the steam available to drive out the air.

All of these studies must be performed by people with the experience, training and equipment to do them properly, or what is known as a process authority.

It is important to remember that heat resistance, heat penetration, and temperature distribution studies are also important for establishing the safety of some cooking and pasteurization processes. The techniques used for establishment of those processes are much the same as those used for retort processes.

Retorts

There are a number of different types of retorts. The first one we will discuss is called a **horizontal still retort**. It is called a horizontal retort because it looks like a large metal cylinder lying on its side. It is called a still retort because the product remains stationary (non-agitated) during processing. There are also vertical retorts and agitating retorts. Most retorts in use in the U.S. and throughout most of the world are still retorts. They are pretty well split between vertical and horizontal types.

FDA's low acid canned food regulations, 21 CFR 113, have very specific requirements for the design of many retorts. However processors can deviate from those requirements if a temperature distribution study shows that the retort has adequate temperature distribution. In this module we will not cover all of the details of each retort system. We will try to briefly explain the different plumbing and control systems and how they make the retort work. For a more detailed explanation of retort systems, refer to FDA's Guide to Inspection of LACF Manufacturers parts 1,2 and 3.

First the containers are loaded into crates and then into the retort and the door is closed and secured. Steam generated by a boiler is delivered to the retort(s) through a pipe called a steam supply header. There must be a sufficient steam supply in the header to adequately vent all the retorts that may be operating simultaneously. From the header, the steam moves into the retort through the steam inlet pipe. There is normally an automatic controlling valve and a hand control valve in the steam supply line (pipe) to the retort.

Very often the hand valve, or bypass valve, is used at the beginning of the process when a lot of steam is needed to heat up the retort walls and containers and drive the air out. After that initial period - the vent cycle and come-up period - it can be closed and the automatic valve can take over. The bypass can also be used in the event of a power outage if power is lost to the automatic control valve.

In a horizontal retort the steam usually enters the retort through the bottom, and is distributed throughout its length by what is called a steam spreader. The steam spreader could be at the top of the retort - but it has to be opposite the vents. The spreader has small holes strategically placed to evenly distribute the steam throughout the retort.

As the air is being driven out of the retort, it leaves through one or more vents. Vents are nothing more than pipes that penetrate into the interior of the retort. These may be a single large pipe controlled by a single valve, a series of smaller pipes controlled by single valves, a series of smaller pipes connected to a large manifold controlled by a single valve or venting may be through the water spreader in the top of the retort which is connected to a large pipe with a single valve. The valve(s) allows air to exit during the venting cycle and the retort system to be closed off when venting is completed. Vent pipes and manifolds may end inside of the plant or may exit the plant to the exterior. The important thing is that the air is allowed to freely escape during the vent cycle. After the vent cycle is completed, the vent valve is closed, and the retort is allowed to heat up to the processing temperature.

A small amount of air may still be caught up between the containers or enter along with the steam. This is removed by smaller valves or openings, called bleeders. They are open throughout the heating cycle. If they are working properly, you can see steam escaping the bleeder.

In some types of retorts, bleeders are also needed at the bottom of the retort to remove condensate - steam that has condensed to water - so that the containers do not become submerged in water.

After the heating cycle is completed, the containers are cooled. Usually, that is done by pumping water into the retort, although sometimes, the crates of containers are moved to a cooling canal or are air cooled.

In most horizontal retorts the water line is connected to a spreader in the top of the retort for spray cooling and to the bottom of the retort to provide for cooling by flooding the retort. With certain cans - usually large cans or aluminum cans - the cans would buckle if they were sprayed with cold water immediately after heating, without taking special precautions. That is because tremendous pressure is developed inside the can as water in the food is turned into steam during the retorting process. To prevent buckling, air pressure is introduced into the retort along with the water. That keeps the pressure on the outside of the cans balanced with the pressure inside of the cans.

It is important not to have air leakage into the retort during the process. Valves used on air lines must be of the type that provide for a non-leaking seal.

There also has to be a drain line and valve for getting the water out of the retort and an overflow line and valve to remove excess water during cooling.

The control systems on a retort include a recorder thermometer, a mercury thermometer and a pressure gauge. The sensor for the recorder thermometer is located next to the mercury in glass thermometer. This location is very important to insure that the mercury thermometer and the recording thermometer can both be correlated to accurately reflect the temperature of the steam in the retort.

The probes on the indicating and recording thermometers stick down into the steam in the retort. Some are located on a bubble-like well that protrudes from the side of the retort. When they are, the well is equipped with a bleeder to keep steam moving past the instruments.

The recorder may also be a controller. That is - not only does it record the temperature that it senses, it also controls the amount of steam entering the retort, in order to keep the temperature as close as possible, but never below, the desired set point. The mercury thermometer must be calibrated at least annually, and the recorder thermometer should be checked against the mercury thermometer - and adjusted if necessary - every batch. The recorder thermometer should never read higher than the mercury thermometer, since the mercury thermometer is considered the accurate reference thermometer.

That brings us back to the steam control valve. In many cases an air pressure line from the controller is used to regulate the status of the valve. This type of controller is very common in the United States and has been in use for over 30 years. The air pressure works on a diaphragm in the valve to open the valve when more steam is needed. The valve is closed by spring pressure working against the air pressure. Air to open is also a safety factor as the valve will close if the control system power is lost, allowing the retort to shut down and not be over pressurized. There are several other types of control systems which may be used including those that work directly off of the retort pressure and those that employ electrically controlled valves.

One of the most important things to remember in retort operation is that timing for the process cannot start until the retort has been properly vented and the mercury thermometer indicates that the retort is up to the processing temperature. Venting can be influenced by the can size, the construction of the crates used to hold the cans, the initial temperature of the cans, the use of divider plates between crates of cans, and a variety of other conditions. Temperature distribution studies have to be done carefully to represent the worst case conditions.

Vertical Steam Retorts are very similar to horizontal still steam retorts, but there are some differences. Steam spreaders are not required on vertical retorts. When they are present on vertical steam retorts they are usually in the form of an "X" at the bottom of the retort.

The vents are a bit different. In most cases there is only one vent. The vent is located in the top lid or on the side of the retort, in which case it is often combined with the overflow line. The vent line must break to the atmosphere so that there is no back pressure on the air exiting during the vent cycle. Water, air, drain, overflow and bleeder systems are all much the same as those discussed for the horizontal still steam retort. The control instrumentation is also the same as for the horizontal still steam retort.

There are a variety of retort designs - some of them extremely complex. We could spend this entire course on the different types of systems and how they operate. However we intend only to mention several of these other systems.

The **crateless retort** is a variation of the vertical still retort. In many ways it works much like the standard vertical retort. However as the name implies, it has no retort crates. Before loading it is partly filled with water which is at or above the desired initial temperature of the cans. The cans fall from a conveyor through an opening in

the top of the retort into the cushion of water. The lid is then closed, and steam is admitted at the top, driving out the water, and venting the retort at the same time.

After retorting and cooling, the lower door is opened, and the cans tumble onto a conveyor. In some installations the cans fall into a cooling cannel where they receive the final cool as they are being conveyed to a can handling system.

Hydrostatic Retorts are several stories tall. They are really a still retort, operating at a constant steam temperature, through which the cans are conveyed for the desired process time. To make it all work there are three legs or sections - an in-feed leg, the steam dome, and the discharge leg. The steam dome, as the name implies is filled with steam at the desired process temperature. The pressure of the steam is balanced by the weight of water in the infeed and discharge legs. That is why they are so tall - because it is under pressure, the steam is trying to escape, but is held in place by the weight of the water. Of course, the steam tends to heat up the water, so the water is warmer near the steam-water interface, at the bottom of the two water legs, than at the top. Cans move through the retort on a conveyor, entering the top of the infeed leg, making several passes through the steam dome, and exiting the discharge leg. Very often there is also a cooling tower, where water cascades over the cans as they pass through the tower. The length of the process is controlled by controlling the conveyor speed. The process temperature is controlled the same as it is in a traditional retort. However the process temperature can only be regulated within set temperature ranges. Operation of the retort at higher temperature than those for which it was designed requires the addition of higher water legs to balance the increased pressure in the steam dome. As with the crateless retort, the infeed water temperature affects the initial temperature of the cans, and so it must be controlled.

Temperature in the steam dome is monitored in the traditional way, with the sensors being located just above the steam/water interface. The level of the steam water interface is also controlled. If it rises to high, it will touch the cans, effectively shortening the **thermal process** time.

One of the real advantages of this system is that it only has to be vented once at the beginning of the day, then it keeps working throughout the day or for several weeks.

Continuous agitating (Sterilmatic) retort systems are more complex. Like the hydrostatic retort the cans move through the system on a conveyor of sorts - in this case a spiral track inside the retort shell. It is called a continuous retort because the reel inside the retort causes the containers to continuously move through the retort. It is called an agitating retort because as the cans roll and slide along the spiral track, their contents are agitated by the headspace bubble. That produces forced convection heating, which, in many foods, results in a shorter cooking time, improved product quality, and increased efficiency. Agitation in this system is known as discontinuous agitation because the headspace bubble moves through the product only during part of each reel revolution.

Like the hydrostatic retort, the system gets vented once at the start of the day, and then operates at a constant temperature throughout the day or until the retort is shut down.

Containers are fed into the retort through an infeed valve, which allows the containers to enter with a minimum of steam loss. In most cases this retort system is used for metal cans. However in some cases it has been modified to process glass jars using metal carriers. The containers are moved along the spiral track by a reel that spins at a preset speed - a lot like the action of an auger. The length of the **thermal process** is determined by the speed of the reel and the length of the retort shell. The temperature of the **thermal process** is controlled in the traditional manner. Usually there is also a cooling shell, in which the cans may be cooled under at atmospheric pressure or under overpressure. The cans move between the cooking and cooling shells by way of a transfer valve - like the infeed valve. The number of shells depend upon the heating and cooling requirements of the product. All of the shells are connected to the same drive motor to keep the operation in time.

Minimum headspace, maximum viscosity, minimum vacuum, and can diameter are important in this type of processing, because they influence the way the contents of the can are agitated as the can moves through the cooking shell - and the degree of agitation affects the adequacy of the thermal process.

The **Orbitort retort** is similar to the continuous agitating (Sterilmatic) retort, except that it is operated in a batch manner or discontinuous manner. The cans are fed into the cooking shell in much the same way, but during the thermal process the spiral track disengages from the shell and engages the reel to lock the cans in place, allowing the cans to be agitated without advancing through the retort. The agitation is continuous in this retort system as the headspace bubble is forced through the product during the entire revolution of the reel. At the end of the cooking and cooling cycles, the track is re-engaged, and the cans move out of the retort. Process controls are essentially the same as with the Sterilmatic retort. This type of retort is used for very viscous products such as cream style corn in large containers.

So far we have for the most part discussed steam retorts, and they certainly are the most common. However a number of retorts operate using a mixture of steam and air, or super-heated water.

The steam/air retorts are a bit beyond the scope of this course, but it's worth while to talk about the water retorts. These are particularly useful in the processing of jars and pouches. Some are still and some are agitating.

Water Processing

Jars and pouches have one very important difference from metal cans - they cannot withstand the internal pressures that cans can. The pressure inside these containers is actually greater than the pressure in the retort. That's because air trapped inside the container expands more than steam does. Cans can withstand this pressure differential. Jars and pouches would loose their hermetic seal. To compensate, additional pressure is added to the retort - in the form of compressed air.

The jars or pouches are heated in a bath of superheated water and pressure is exerted on the surface of the water by compressed air. A water bath is used because, without some very sophisticated controls, the mixture of steam and air necessary to maintain the hermetic seals would cause cold spots to form, as was discussed when venting was outlined.

Processing in water eliminates the problem of cold spots from air in the retort, since the air will rise above the water. It also eliminates the need for venting. Cold spots in the retort still have to be eliminated through a timed come-up process.

In vertical still retorts, air is introduced below the water to help agitate the water as it moves through - improving temperature distribution. Since air is brought into the retort throughout processing, the desired pressure is assured by controlling how much air exits through the pressure relief or overflow valve. Temperature distribution is improved in horizontal water retorts by pumps that circulate the water.

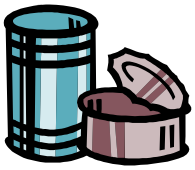
During cooling, the steam supply is shut off and cold water and air are introduced into the retort, maintaining sufficient over-riding pressure to prevent loss of the hermetic seal.

In addition to controlling the temperature of the water, and the pressure inside the retort, control of the water level in the retort is critical. If it falls below the tops of the containers, those containers will be under-processed. A sight gauge or petcock is usually used for control, but automatic monitoring devices are also available.

Container Integrity

Up to now, we have discussed how to deliver the thermal process to the product to eliminate spores of *C. botulinum*. That's only half the story. The product container must be constructed so that *C. botulinum* bacteria and other pathogens can't re-enter the container after the thermal process. That is called container integrity.

Metal Containers



Traditionally cans were manufactured from three pieces of tinned steel plate - the body, and two ends. Many are still made that way, but for the most part tin-free steel is now used. There are also what is called a 2 piece can where the steel is extruded making the side and bottom one seamless piece. In the past, the side seam was hooked together and then soldered. Now, most three piece cans have welded side seams. The ends are joined to the body in what is called a double seam. In most cases, the side seam, if there is one, and the bottom end double seam are produced by the can manufacturer, under carefully controlled conditions. However, the top end double seam is produced by the food manufacturer, under the less than ideal conditions of the processing room. For this reason, we tend to concentrate our attention on this seam.

The flange at the top of the body is flared outward - and the end curl is bent down and up inside the flange - this forms the double seam. Seaming compound that is in the end curl serves as a gasket to further complete the seal.

The flange of the body is formed into what is called the body hook during seaming. The end curl interlocks with the body hook and is called the cover hook. The degree or length of interlock between the body hook and cover hook is called the overlap. It is the only section of the seam where there are five layers of metal. The amount of overlap is critical to the security of the seam. The distance across the finished seam parallel to the side of the container is known as the seam width, length or height. The distance across the seam perpendicular to the side of the can is the seam thickness. The distance between the top of the double seam to the end panel is called the countersink. The double seam is judged by these measurements along with some other evaluations, such as pressure ridge and wrinkle rating. Evaluations are based on guidelines provided by the container manufacturer.

These seam guidelines assist the processor in maintaining acceptable seams during production.

The double seam for a metal can is formed in two stages on a piece of equipment called a seamer or closing machine. The seamer has four basic parts; the seaming chuck that fits inside the can cover and supports the can against the seaming rolls; the base plate that lifts the can and can end up to the seaming chuck and applies upward pressure during the seaming cycle; and two (2) seaming rolls, the first of which basically forms the seam while the second tightens and flattens the metal forming its profile. These four basic parts are adjustable and the adjustment is critical in obtaining a well formed double seam.

Basically, it works like this: The can is placed on the base plate, the cover is automatically placed on the can, the base plate lifts the can and cover onto the seaming chuck tightly clamping the cover onto the can. Then the first operation seaming roll is brought into contact with the can and cover, and the first operation roll is formed - it can be described as curling the cover hook around the inside of the body hook to form an interlock. Then the second operation roll is brought into contact with the can and cover and it flattens the seam and irons out any wrinkle in the can seam.

Seamers are generally of two (2) types: One, where the can spins on the base plate and chuck at a high rate of speed while stationary rolls swing in to make contact with the can and then swing back out after the seaming operation is complete. Or the other, where the can, base plate, and chuck are stationary and the two rolls travel around the stationary can, forming the double seam. Either way, after the base plate drops, the can is moved down the line and into a retort crate.

There are two ways to measure the can seam specifications. One is what we call the optical method and the other is the micrometer method.

The optical method requires a machine - a seam scope or a computer. First, the seam is cut through from top to bottom and a cross-section is placed on the projection device. The device allows you to make all of the measurements that we talked about, including overlap.

The micrometer method requires measurements - using a micrometer -of the seam width, and thickness of an intact can. Then, the can seam is torn down so that the cover hook and body hook are disengaged without damaging them and then measured. Once the width, cover hook and body hook are measured, the overlap can be calculated.

This micrometer method also lets you look at the cover hook for what is called wrinkle. Wrinkle exists in the cover hook if not enough pressure is exerted in the second seaming operation to iron them out. Wrinkle examination - or tightness rating - is another very important step in ensuring container integrity.

But if the seamers are not maintained or seam guidelines are not adhered to lots of things can go wrong. We will discuss a few of the more common seam defects:

Droop - is a smooth projection of the double seam below the bottom of a normal seam - if the droop is excessive, the cover hook will be too short - or maybe even non existent so there is no overlap. These defects are caused by things like a loose first operation roll, or tight second operation roll - or sometimes product gets caught in the seam.

Cutover - is where the top of the inside portion of the seam has become sharp enough to fracture the metal. This can happen if the seaming chuck is worn or broken or if there is excessive base plate pressure, or if the first and second roll operations are too tight.

False seam - is where a portion of the seam is completely unhooked and the cover hook is compressed against the folded body hook. This one is not always detectable by a visual examination. These can be caused by the can not being centered on the chuck, or if the cover curl is bent or damaged before seaming, or if the seamer is out of time.

Those are just a few of the possible can seam defects. There are lots of defects that can happen if the processor is not careful. For control, processors are required to perform both external visual examinations of the double seam - to look for these types of defects, and also a teardown examination to make sure that all of the seam guidelines are met and the integrity of the double seam is assured. These requirements are outlined in FDA regulations 21 CFR part 113. They are also discussed in FDA's Guide to Inspections of Low Acid Canned Food Manufacturers Part 3.

Glass Containers

Contrary to popular belief the hermetic seal on most glass jars has little to do with contact between the threads or lugs on the jar and those on the cap. The seal is made where the gasket inside the cap contacts the top of the jar.

Let's review a few terms that apply to glass containers. The finish is that portion of the jar that surrounds the opening. It includes the sealing surface and the lugs or threads. The lids or closures also contain lugs or threads, as well as the gasket, which meshes with the sealing surface of the jar. The gasket is either made of rubber or a plastic material, called plastisol, that softens with heat. Another important term is the mold seam or vertical neck ring parting line on the jar, where the two halves of the jar neck ring are joined.

The lugs and threads serve to mechanically hold the lid in place. However, the seal is the result of the internal vacuum holding the lid firmly against the sealing edge of the finish. Vacuum is, therefore, critical to the integrity of glass containers. Measurement of vacuum after processing is an important control procedure for these containers.

A number of factors effect the processor's ability to obtain the desired vacuum - the headspace above the product in the jar, the temperature of the product, and proper operation of the equipment that draws a vacuum on the headspace or sweeps the headspace with steam.

Commonly used post-processing measurements are what are called pull up and security. **Pull-up** is the distance between one of the neck ring mold seams and the front of the nearest lug measured in 1/16 inches. The jar/closure combination is designed so that this value will be constant if the lid is properly applied. A measurement too far to the right (+) from the line and the lid may be under applied, a measurement too far (-) to the left of the line and the lid may be over applied. Proper pull-up limits will be supplied by the glass or closure manufacturer. Pull-up can be related to security after a number of tests.

Security is measured by marking the lid and the jar at a common point, breaking the seal, and retightening the lid until contact is just made between

the gasket and the sealing surface. The distance between the two lines is then measured in 1/16 inches. The cap line should end up to the right of the jar line, demonstrating that the capper exerted adequate torque on the cap, creating the seal. Proper limits for security will be provided by the glass or closure manufacturer. On a properly applied cap, there will a uniform impression in the gasket made by the sealing surface of the jar, all the way around the cap.

As with can seam examinations, processors should also perform visual, external examinations, looking for cocked caps, and other obvious defects. Many food caps also have a flipper button that remains in the down position as long as the vacuum is in place, and pops up when the vacuum is broken.

Retortable Pouch

One last container type that we want to briefly mention is the retortable pouch. The seal on these containers is achieved by fusing the two walls of the pouch together, usually by heat. In multilayered pouches, such as the ones that contain a metal foil or paper layer, only the inner layer is fused.

Seal integrity is determined by following the container manufacturer's recommendations. One of the most important tests to ensure the security of these seals is a burst test, where pressure is applied until the seam fails. Seal strength should meet the container manufacturer's specifications. Seal strength is also often checked by cutting a section across the seal and mechanically pulling the seal apart. This is a test of the seal's tensile strength. The test is a useful adjunct to the burst test, but only tests a small portion of the seal. Visual examination should also be performed on every container after processing to ensure that the seals are complete.

FDA's low acid canned food regulations have very specific requirements on the nature and frequency of container seal examinations for metal and glass containers but not for other container types.

Even with the best container seal, the potential for leakage exists, and is at its greatest risk during the cooling cycle. At this time, the interior of the container goes from a pressure condition to a vacuum. The vacuum tends to draw in any contaminants on the outside.

Flexing of the seam due to the these changes also results in a reduced ability of the seam to prevent that kind of contamination.

If containers are air cooled after retorting, the area where they are cooled should protect the containers from external contamination such as rainwater, birds and rodents, and from employees that may sit on, handle or place their outer garments, gloves or aprons on the containers.

If the containers are water cooled, cooling water should contain residual chlorine or other sanitizers to reduce the risk of contamination.

Aseptic Processing

One last type of thermal processing is aseptic processing. Up until now we have been talking about retorting operations where the product is heated in the final, hermetically sealed container. In aseptic processing the product is heated in a process designed to inactivate *C. botulinum*. and is then filled into pre-sterilized containers, in an aseptic environment.

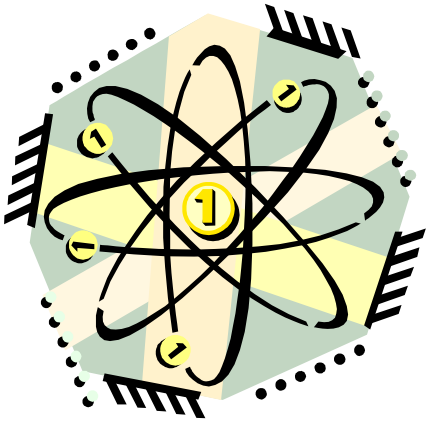
As it sounds, it is pretty complex. A number of things have to be done correctly in order for this process to work - if the process and manufacturing procedures are done correctly the product is shelf-stable.

Like traditional canning, the process must be adequate to inactivate the spores of *C. botulinum.* This is done in equipment very much like the continuous pasteurization equipment used for fluid products, that we discussed earlier. These processes are normally used for liquid and semi-liquid products containing pumpable particulates.

The packaging material is either preformed or is formed directly on the packaging equipment. Either way, it is sterilized using heat, radiation, or chemicals, before it is filled.

Finally, the thermally processed product and the sterilized containers are brought together in an aseptic environment. To achieve that kind of environment, the equipment is sterilized with steam, hot water, or chemicals, and positive pressure in the filling chamber is assured by the introduction of incinerated or hepa-filtered, sterile air.

Emerging Technology For Microbiological Control



Objectives

This module will introduce the student to several processes used for microbiological control including:

- Irradiation
- High Intensity Pulsed Light
- High Intensity Pulsed Electric Fields
- UV Light
- High Pressure Processing
- Ohmic Heating & Aseptic Particulate Processing
- Ozone

Overview

The food industry continues to expand the use of current methods and to search for new technology which will provide for microbiological safety in food products while at the same time providing the consumer with products of high quality which appear to have experienced little or no processing. Irradiation, high intensity electrical fields, pulsed light; UV light, high pressure processing, and ozone, have been recognized for several years as non-thermal methods for microbiological destruction. However, commercial development using some of these technologies has only come about in the last few years. While many of these new technologies that will be discussed along with others appear to be able to deliver the expected results, they usually also have limitations which prevent their use in all situations. The advantages, disadvantages and limitations of each process must be understood when applying these new technologies to existing products, new products, or to meet the concerns of new or emerging pathogens.

Irradiation

- Gamma ray
- Accelerated Electron
- Radappertization
- Radicidation
- Radurization

Irradiation is another way to destroy microorganisms. Irradiation is the general term used to describe exposure of a product to ionizing radiation.

Gamma Ray & Accelerated Electron Radiation

Some common forms of ionizing radiation that we might be familiar with are X-Rays, microwaves, and ultra violet light. Although these other forms do have applications in the food industry, in this section we are going to focus on two other forms, gamma ray and accelerated electron radiation. Both these forms have practical applications in the destruction or reduction of microorganisms in food products.

The FDA has approved irradiation of pork, beef, poultry, lamb, spices, seasonings, and dry enzymes. Radiation has also been approved for use on fruits, vegetables, and grains to destroy insects. The requirements for irradiation of food products can be found in 21 CFR Part 179.

Every technology has its own terminology and radiation is no exception. **Kilogray** is the term used by the food industry to describe the amount of radiation applied to the food.

There are several factors that affect a microorganism's resistance to radiation including:

number of organisms

type of organisms

age of the organism

presence or absence of oxygen

characteristics of the food

There is strength in numbers. The more microorganisms present, the more radiation that is needed to eliminate them.

In general:

- Spores are more resistant to radiation than vegetative cells.
- Gram positive bacteria are more resistant to radiation than gram-negative bacteria.
- Yeast are more resistant to radiation than molds.
- Microorganisms are more susceptible to radiation during the growth phase of their life cycle.
- An organism's sensitivity to radiation is greater in the absence of oxygen.
- High protein foods and dry foods offer increased protection to microorganisms from radiation.

Irradiation processes must be scientifically designed to provide the desired reduction in microorganisms with the least amount of radiation. There are a few terms that describe the level of microbial reduction, just like in thermal processing.

Radapperation is comparable to commercial sterilization. Food products exposed to radiation levels between 30 and 40 kilograys are considered to be commercially sterile.

Exposure to radiation levels between 2.5 and 10 Kilograys will rid most foods of all vegetative pathogens. This level or irradiation is called **radicidation** and is comparable to pasteurization.

Exposure levels of between 0.75 and 2.5 Kilograys will rid most foods of spoilage organisms. This process is called **radurization**.

Cobalt 60 or Cesium 137

Commercial irradiation of food products normally relies on either gamma rays or accelerated electrons. Gamma ray irradiation is accomplished using Cobalt 60 or Cesium 137 as the radiation source. An electron beam accelerator is used to generate electrons for food irradiation.

Facilities using Cobalt 60 are geared for large-scale product irradiation. Cobalt rods, about the size of a pencil provide the gamma rays, which are stored in the center of the unit inside of a 30-foot deep shielding pool of deionized water. The cobalt irradiator uses concrete walls 10 foot thick, with an intricate systems of locks and other safety features to protect the employees and others from accidental radiation. Foods are loaded into carriers, which travel to fixed locations around the exposed source material. The amount of radiation to which the food is exposed is determined by the dwell time in that part of the unit exposed to the gamma source.

Units using Cesium-137, as the gamma source may be smaller self contained units that do not need external shielding. At least one manufacturer has designed a unit where shielding of the gamma source is fabricated as part of the unit from steel. This unit is designed to accommodate one pallet of food product. When the food product is in the above ground closed chamber of the irradiator, panels containing the cesium move up from an underground chamber and surround the food product being treated.

An advantage to gamma ray irradiation is that gamma rays penetrate virtually all materials and irradiation of even dense food products can be achieved.

A recognized irradiation authority must scientifically establish a gamma ray irradiation process. This is required by FDA regulation, 21 CFR Part 179 - IRRADIATION IN THE PRODUCTION, PROCESSING AND HANDLING OF FOOD. The established process must then be followed and carefully monitored. Critical process controls include time of exposure to radiation, source positioning, and product loading patterns. Cobalt 60 decays over time. This source decay rate must be accounted for in determining product exposure times. Finally, radiation sensitive visual indicators and dosimeters

must be handled correctly and are usually included as part of the firm's quality assurance program.

There are disadvantages with gamma ray systems. Irradiation cannot be directed toward a particular area of the food package. These systems are designed for continuous operation and there is no way to shut off the source. Gamma ray systems are quite expensive and there are source disposal, safety, and environmental concerns.

Electron Beam Facility

A facility using an electron beam is usually less extensive than a gamma ray facility. They are geared to handle irradiation of individual pallets or small lots. An advantage of the electron beam is that irradiation can be directed to specific areas of the food - kind of like an X-ray machine - where specific areas are targeted. That way, radiation exposure to radiation sensitive areas can be minimized. An electron beam can be shut off when not in use and does not have hazardous waste disposal concerns.

However, like gamma ray processes, a recognized irradiation authority must establish electron beam processes. Critical processing parameters must be identified and controlled. These include conveyor speed, electron beam characterization, and product loading patterns. Critical controls would be similar to those required for gamma radiation.

There are some disadvantages with the use of electron beams. Penetration into dense product is limited making the process unsuitable for many types of food.

Some foods cannot tolerate exposure to radiation, either gamma or electron beam, because it changes the flavor, texture, or other quality attributes. Also, the loss of desirable nutrients can be a problem. Thiamine, in particular, is sensitive to radiation exposure. Irradiation can result in the production of radiation by-products called radiolytic compounds. These by-products are considered food additives, which must be evaluated for safety.

And finally, the public concern over the use of food irradiation has resulted in a requirement that irradiated foods bear the universal radiation label and other appropriate labeling.

MICROBIAL DESTRUCTION BY IRRADIATION	
ADVANTAGES	**DISADVANTAGES**
Effective against all types of microorganisms	May be more expensive than other available technologies
May be less destructive to some heat sensitive foods.	May cause changes in the food product and must be approved for food additive use on that product
Will extend product shelf life of products	Gamma ray facilities may involve safety and environmental concerns
Gamma rays can penetrate dense materials, products can be treated inside of large cartons or pallets	Electron beams will not penetrate dense products
	Public perception of irradiation must be overcome

High Intensity Pulsed Light

- Rapid Intense Flashes of Light from Inert Gas Lamps
- Millionths of a Second
- Ultraviolet through Near-Infrared Spectrum
- 20,000 times the Intensity of Sunlight at Sea-level

High intensity pulsed light involves the application of rapid, intense, magnified flashes of light. The pulsed light is produced using engineering technologies that multiply power by accumulating electrical energy in an energy storage capacitor over relatively long periods of time (fractions of a second) and releasing this energy over short periods of time (millionths or thousandths of a second). The stored energy pulses an inert gas lamp to produce an intense flash of light lasting only a few hundred microseconds. The number of lamps, the flashing configuration, and the flash rate depend upon the product application. The pulsed light contains wavelengths from 200 nm of ultraviolet through 1 mm in the near infrared at about 20,000 times the intensity of sunlight at sea level. Most of the pulsed light is in the visible range. Ionization of small molecules does not occur because the pulsed light wavelengths are too long.

The antimicrobial effects are significantly greater than those of non-pulsed or continuous-wave conventional UV irradiation. Pulsed light appears to eliminate populations of vegetative bacteria, bacterial endospores, fungal conidiospores and

eukaryotic organisms (those organisms with a true nucleus) with equal effectiveness. This makes pulsed light technology suitable for treatment of food and water, which may be contaminated with organisms such as *Crytosporidium.* Pulsed light will penetrate foods and packaging materials, which transmit UV. This makes it possible to treat transparent food items such as water, and food items through transparent packaging material. In addition to destruction of microorganism the use of pulsed light deactivates those enzymes which may in some cases lead to product deterioration.

The intensity of the pulsed light treatment is measured as fluence, or incident light energy per unit area, in Joules (J)/cm^2. A Joule is less than 1/4 calorie and more than 4 Joules of energy are required to raise the temperature of 1 gram of water 1 degree C. The application of a single flash at 0.5 J/· cm2 has been shown to eliminate populations of 10^5 vegetative bacteria, bacterial endospores, or fungal conidiospores/cm^2. Reductions of 7-9 logs cfu/cm^2 have been demonstrated with multiple pulses at 1 J/cm^2 per flash.

Information supplied by PurePluse Technologies, San Diego, California for their pulsed light technology (PureBright) to the Food and Drug Administration in the form of a food additive petition has resulted in the acceptance of pulsed light as a source of irradiation in the production, processing and handling of food. The use of pulsed light is covered by 21 CFR Part 179.41 and allows for the use of pulsed light under the following conditions:

(a) The radiation sources consist of xenon flash lamps designed to emit broadband radiation consisting of wavelengths covering the range of 200 to 1,100 nanometers (nm) and operated so that the pulse duration is no longer than 2 milliseconds (msec);

(b) The treatment is used for surface microorganism control:

(c) Foods treated with pulsed light shall receive the minimum treatment reasonably required to accomplish the intended technical effect;

(d) The total cumulative treatment shall not exceed 12.0 Joules/square centimeter (J/cm^2).

FDA review of the data submitted in support of the food additive petition revealed that the use of pulsed light under conditions specified in the petition did not cause harmful photochemical changes in the food products or in the microorganism treated. The foods treated did not sustain a significant reduction in nutritional value.

MICROBIAL DESTRUCTION BY HIGH INTENSITY PULSED LIGHT	
ADVANTAGES	**DISADVANTAGES**
EFFECTIVE AGAINST ALL TYPE OF MICROORGANISMS INCLUDING OOCYSTS	CAN ONLY BE USED FOR SURFACE TREATMENT. LIGHT HAS TO PENETRATE TO BE EFFECTIVE
CAN BE USED TO TREAT PRODUCTS THROUGH TRANSPARENT PACKAGING MATERIALS	EMPLOYEES MUST BE SHIELDED FROM LIGHT SOURCE.
DOES NOT RAISE THE TEMPERATURE OF THE PRODUCT BEING TREATED	INITIAL INVESTMENT IN EQUIPMENT MAY BE HIGH
CAN BE USED TO TREAT PROCESSING WATER AS WELL AS PRODUCTS	EQUIPMENT OPERATION MUST BE CLOSELY MONITORED TO INSURE THAT THE CORRECT TREATMENT IS APPLIED
CAN BE USED TO SURFACE TREAT A LARGE VARIETY OF PRODUCTS	
INHIBITS ENZYMATIC ACTIVITY	

In order to assure that the desired microbial destruction is achieved, lamp fluence and lamp current must be monitored during production Lamp fluence is measured by using silicon photo-diodes to measure the UV content of the light output of the flashlamp. A trend toward reduced output indicates that the lamp is near the end of its useful life. The lamp current is monitored on every flash. A significant deviation above or below a pre-set current level may indicate a problem with the lamp or the electrical circuitry. Systems would normally be designed to monitor the operation of the equipment and shut down the operation if abnormal conditions were detected.

High Intensity Pulsed Electric Fields

- High voltage applied to food products
- Voltage applied in short burst
- Food is treated at refrigerated or room temperature
- Best suited for foods that can be pumped
- Cell walls of microorganisms are destroyed

High intensity pulsed electric fields; (PEF) involves the application of a short burst of high voltage to foods placed between two electrodes. The high voltage required for the process is delivered by building up a reserve of electrical energy in a capacitor, which is then discharged. The treatment is conducted at an inlet ambient or refrigerated temperature for less than 1 sec, and energy loss due to heating of the food is minimized. The process is more suitable to pumpable foods. Inactivation of the microorganisms has been determined to be due to the electrical field and not to the products of electrolysis or Ohmic heating.

Research at this time indicates that the cell wall of the microorganism is destroyed. The process does not appear to change chemical, enzyme, or physical characteristics found in the food product. Processing conditions are determined by the food product characteristics. The process given to any one food product is determined by several variables including the peak electrical field strength(kV/cm) (kilovolts per centimeter), pulse duration (*u*sec) (microseconds), number of pulses, initial temperature, maximum treatment temperature, microbiological organisms of concern and microbiological load. An increase in treatment processing temperature appears to increase the microbiological destruction.

The process is most effective on vegetative cells of pathogenic and spoilage organisms. Destruction of spores requires exposure to long treatment times using high voltage levels. Studies performed on this process indicate that the process will be most useful for pasteurization of pumpable shelf stable acid foods and refrigerated foods which require pasteurization to extend the shelf-life of the food (see table 1).

High-Intensity pulsed electric fields for microbiological destruction of organisms in food products have been investigated in several countries in the world. In the United States one of the leading industrial firms, PurePulse Technologies Inc. San Diego, California has submitted data to FDA to support their high-intensity pulsed electric field process (*CoolPure*) for antimicrobial treatment of liquids and pumpable foods. After reviewing this data FDA determined that a food additive regulation was not needed for this process, as long as Good Manufacturing Practices were followed. No changes were noted in any food products treated using high-intensity pulsed electric fields.

Table 1-PEF Processing Conditions for Selected Liquid Foods

Food	**Apple juice from concentrate**	**Fresh Apple Juice**	**Raw skim milk**	**Beaten eggs**	**Green pea Soup**
Peak electric field (kV/cm)	50	50	40	35	35
Pulse duration (m*sec)*	2	2	2	2	2
Pulse number	10	16	20	10	32
Initial temperature (°C)	8.5?1.5	8.5?1.5	10.0?1.5	8.5?1.5	22.0?2.0
Maximum treatment temperature (°C)	45?5	45?5	50?4	45?5	53?2
Storage Temperature (°C)	22-25	4-6	4-6	4-6	4-6
Shelf Life (days)	28	21	14	28	10

Adapted from Food Pasteurization Using High-Intensity Pulsed Electric Fields Food Technology December 1995.

The use of high-intensity electric fields for microbiological destruction in food products will require processes developed for each individual product. Consideration must be given to the microbiological organisms of concern, the microbiological load on the raw product materials, the characteristics of the product to be treated, the conditions under which the product will be stored, shipped and handled and the ultimate consumer of the product. Specific processing conditions as established by scientific studies would be considered factors critical to the process.

MICROBIAL DESTRUCTION BY HIGH INTENSITY PULSED ELECTRIC FIELDS	
ADVANTAGES	**DISADVANTAGES**
DESTROYS HIGH LEVELS OF PATHOGENIC AND SPOILAGE ORGANISMS	HIGH DOSAGE AND LONGER PERIODS OF TIME NEEDED FOR SPORES
SLIGHT OR NO TEMPERATURE RISE IN PRODUCT	WORKS ONLY ON LIQUID OR PUMPABLE PRODUCTS
ENERGY COST MAY BE LOWER COMPARED TO THERMAL PROCESSING	AT THIS TIME ONLY USED FOR SHELF STABLE ACID FOODS AND REFRIGERATED FOODS
NO NOTED PRODUCT CHANGES, VITAMINS AND ENZYMES ARE NOT DESTROYED	PROCESS MUST BE DESIGNED FOR EACH SPECIFIC PRODUCT

Ultraviolet (UV) Light

- Air and surface disinfectant
- Pasteurization of liquids

UV light is another process on the horizon for pasteurization of some food products . UV light as an air and surface disinfectant has been used for a many years.

There are basically three types of ultraviolet energy grouped according to wavelengths. UVA (longwave) UVB (middlewave) and UVC (shortwave). All UV light waves are shorter than visible light waves and therefore are invisible to the human eye. UV wavelengths generated by UV lamps are lethal to microorganisms in the 253.7-nanometer range.

In order for the ultraviolet rays to kill bacteria and other microorganisms, they must strike the microorganism, and each microorganism must absorb a sufficient amount of energy to be destroyed. The dosage necessary to inactivate a microorganism is a product of time and intensity.

Recently, a process for pasteurizing clear liquids using UV light has been developed. This process involves pumping a thin film of the liquid past UV light at a preset rate. This process has been found to significantly reduce the biological load of the liquid.

Because of the nature of UV light, flow rates, turbidity, product clarity, and lamp output need to be monitored continuously.

As with the other systems, there are limitations. In this case it has to do with penetration of UV light into the product. And, that is why processes, so far, has been limited to clear liquids.

MICROBIOAL DESTRUCTION BY ULTRAVIOLET LIGHT	
ADVANTAGES	**DISADVANTAGES**
SYSTEM COST MAY BE LOWER THAN WITH OTHER SYSTEMS	CAN BE USED ONLY FOR SURFACE OF CLEAR LIQUID FILMS

High Pressure Processing

- Food Subjected to Pressures of 65-80,000 psig
- Food Product Can be In a Flexible Package
- Pressure May be Produced in Pumps With Aseptic Packaging
- Changes the Structure and Permeability of the Cell Wall

The pressure processing of foods for preservation was studied as early as the end of the 19th century and the beginning of the 20th century in the United States by people like Hite (1899) and Bridgman (1914). However the potential microbiological effects of pressure processing was not recognized by the food industry until around 1985. High Pressure Processing (HPP) has recently received a great deal of attention in the food, pharmaceutical and biotechnological industries. Japan has been a leader in this technology producing products such as jams, jellies, fruit juices and yogurt.

High pressure processing of foods requires pressures of 4000 - 6000 bars (65-80,000 psig). High pressure processing in other industries may use pressures of up to 100,000 psig. This type of processing requires very specialized equipment. If the food is packaged in a flexible or semi-flexible package the pressure processing may take place after the food has been placed into the final package. In this type of process a batch system would be used in which the product would be placed into a chamber filled with water and subjected to the high pressure for a time of 1 - 20 minutes. The camber would then be depressurized and the product removed. Some food products such as juice may be batch processed in a pressure chamber and then aseptically filled into pre-sterilized containers. Research is also being performed on systems, which will use high-pressure pumps to subject liquid foods, such as apple juice, to the required high-pressure process. These liquid foods could then be filled aseptically into sterile containers.

High pressure processing may induce some changes in food products including changes in texture. High pressure processing induces gelling in proteins. Enzymatic action may be enhanced in some products where the cell wall is broken down. The process has no effect on food spoilage organisms and these enzymes must be blocked by some other action such as blanching. Whole fruits and vegetables may be distorted by the mechanical compression, thus making more nondescript forms of fruits and vegetables such as juices, jams, diced, segmented and mixed foods such as salsa more likely candidates for pressure processing.

Microorganisms vary in their sensitivity to high pressure. Pressure processes must take into account the organism of concern, product characteristics, the process desired (pasteurization or commercial sterility) and how the product will be held and sold (refrigerated or shelf stable). Destruction of the microorganism is primarily caused by changes in the structure and permeability of the cell wall which causes fluids to be forced into the cell.

Research indicates that high pressure processing in the range of 50,000 to 100,000 psi are very effective against vegetative bacteria, yeast and molds in products with water activity close to 1. However spores resist inactivation by high pressure alone and may require the addition of heat or some other mechanism to achieve high levels of destruction. Because of this the best candidates for pressure processing continue to be acid foods and foods which will be refrigerated following processing.

MICROBIAL DESTRUCTION BY HIGH PRESSURE	
ADVANTAGES	**DISADVANTAGES**
NO HEAT IS APPLIED DURING PROCESS, FOODS RETAIN FRESH APPEARANCE.	ENZYME ACTIONS MAY BE ENHANCED
PROCESS CAN BE APPLIED TO PRODUCTS IN FINAL PACKAGE	MAY CAUSE PROTEINS TO GEL, STARCHES TO SWELL
PROCESS CAN BE APPLIED AS PART OF ASEPTIC PROCESS FOR LIQUID FOODS	CAUSES CHANGES IN FOOD TEXTURE
ENZYME ACTIONS MAY BE STOPPED	HIGH INITIAL COST OF EQUIPMENT
	SPORES OF BACTERIA, MOLDS AND YEAST MAY REQUIRE VERY HIGH PRESSURES AND LONG PERIODS TO BE DESTROYED

Ohmic Heating

- Heating Through the Products Own Conductivity
- Alternating Electrical Current Applied to the Product
- Depth of Penetration is Unlimited
- No Large Heat Gradient in Product
- Heating Controlled by Conductivity of Product and Residence Time in the Heater
- Microbial Destruction is by Heat

Ohmic heating and aseptic particulate processing continue to use the time tested method of thermal destruction of microbiological organisms, while at the same time using new methods of product heating and process determination to insure that the thermal process is delivered to the product.

The Ohmic heating effect occurs when an alternating electrical current is passed through a conducting product (Fig. 5). In common with microwave heating, electrical energy is transformed into thermal energy. However unlike microwave heating, the depth of penetration is virtually unlimited and the extent of heating is governed by the spacial uniformity of electrical conductivity throughout the product and its resistance time in the heater. For most practical purposes the product does not experience a large temperature gradient within itself as it heats, and liquid and particulates are heated simultaneously.

Ohmic heating is best suited for aseptically packaged products. Equipment used for processing and packaging other aseptic products can be used for processing Ohmic heating products. The major difference in an Ohmic aseptic system and any other aseptic system would be the method of heating.

Because Ohmic heating uses the resistance of the food product and a commercial electric current to heat the food there are advantages over conventional heating systems including: lack of burn on to the heating surface, product does not have to agitated during heating, liquid carrier does not have to be overheated to heat particulates and particulates heat uniformly throughout.

Ohmic heating is dependent upon the electrical conductivity of the product. Most food products contain a moderate percentage of free water with dissolved ionic salts and conduct sufficiently well for the Ohmic effect to be applied. Ohmic heating however will not directly heat fats, oils, alcohols, bone or crystalline structures such as ice.

Ohmic heating uses thermal destruction for microbiological control similar to other thermal processing systems. There are however several considerations which must be taken into account when designing an Ohmic heating process. The specific electrical resistance of the product and its changes with temperature must be determined and controlled during the commercial application of the process. Product flow rates are critical to the heating of the product. The velocity of the product in the

Ohmic heater and the heating rate are important considerations. If the product changes states in the heater (from a liquid to a solid or liquid to a gas), arcing may occur in the product. For these reasons design considerations have to be product specific for most applications.

Successful Ohmic processing of foods to destroy microbiological organisms requires strict controls over the Ohmic process. Operating procedures should follow those established by a knowledgeable person. Strict control should be maintained over: product formulation, flow rates, product temperatures in the hold tubes and any other factor found to be critical to the process.

Ohmic heating does however provide promise to those firms who wish to produce high volume, high value low acid shelf stable products which contain particulates and to those firms who manufacturer acid and refrigerated foods which require only pasteurization processes.

OHMIC HEATING	
ADVANTAGES	**DISADVANTAGES**
STERILIZES PARTICULATES UP TO ONE INCH IN DIAMETER	PROCESS DEPENDS ON PRODUCT CONDUCTIVITY TO PRODUCE HEAT
MINIMAL MECHANICAL DAMAGE TO PARTICULATES	WILL NOT WORK WITH FATS, OILS ALCOHOLS, BONE OR ICE
UNIFORM HEATING OF PARTICULATES	PRODUCT FORMULATION MUST BE CAREFULLY CONTROLLED, TO CONTROL ELECTRICAL RESISTANCE
AVOIDS OVER PRECESSING OF CARRIER FLUIDS	PRODUCTION EQUIPMENT MAY HAVE TO BE DESIGNED FOR SPECIFIC PRODUCTS
CAN PROCESS UP TO 80% SOLIDS	PROCESS FOR PARTICULATE LOW-ACID SHELF STABLE FOODS ARE DIFFICULT TO DESIGN AND DOCUMENT
MINIMAL FOULING OF EQUIPMENT NO HEAT TRANSFER SURFACES FOR PRODUCT HEATING	SOME FOODS MAY REQUIRE REPROCESS TREATMENTS WITH HEAT OR CHEMICALS TO INITIATE OR ALTER CONDUCTIVITY
LESS NUTRIENT, COLOR AND FLAVOR DEGRADATION	PRODUCT FLOW RATE AND TEMPERATURE HAVE TO BE CONTROLLED TO INSURE THE MICROBIAL DESTRUCTION

Ozone

- Bactericide
- Processing water treatment

The final system that we will discuss in this section is ozone. The use of ozone as a bactericide is not new. Like chlorine, ozone oxidizes organic substances. It is used for elimination of pathogens in processing water, for example by vegetable processors. This treatment allows the processing water to be reused rather than dumped. It has been used for many years to treat drinking water in the United States and other countries. Another advantage is that ozone, unlike chlorine, leaves no toxic residue in the treated water.

Ozone is also used as a surface treatment in enclosed areas where there is a potential for contamination of food, such as refrigerated meat lockers. It can reduce or eliminate mold on both the locker surfaces and on the surfaces of the carcasses in the lockers.

Ozone has potential use as an alternative to chlorine. It is a more powerful disinfectant and can destroy a large number of different microorganisms. One of the potential uses is for sanitizing fresh fruits and vegetables. At this time the use of ozone for sanitizing fresh fruits and vegetables has not been approved by the FDA.

MICROBIAL DESTRUCTION BY OZONE	
ADVANTAGES	**DISADVANTAGES**
Can be used to eliminate pathogens in water	Not approved for treatment of other food products by FDA
Leaves no toxic residue in water	
Effective against a wide range of organisms	
Can be used as surface sanitizer for lockers and meat	

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